PRIORITY ANALYSIS FOR
RANKING OF TRANSPORTATION IMPROVEMENT PROJECTS -
A PROPOSED PROCEDURE

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SUMMARY

This research describes the development of a priority analysis procedure designed to suit the needs of the Georgia State Department of Transportation. The procedure is based on a 'scoring model' approach. It allows highway projects to be evaluated in terms of up to 26 factors that are divided into eight groups: need, deficiency, continuity, benefit-cost, local opinion, economic, social and environmental factors. The improvement projects are categorized according to 10 functional classes and eight types of improvement. Factor selection and a preliminary set of weighting factors were determined from responses to questionnaires distributed to State Transportation Board members, Department of Transportation officials, and regional and local planners. The individual factors are combined by the model into one or two indices that can then be used to rank the projects within each category. Comparisons between categories cannot be made at this time. This research developed a complete framework for a priority analysis procedure. However, more work remains to be done in developing units of measure and criterion values for the evaluating factors. The procedure also needs to be tested and calibrated before implementation.

CHAPTER I

INTRODUCTION

This research is directed towards the development of a priority analysis procedure for ranking highway improvement projects for the Georgia State Department of Transportation. This work was performed through the joint cooperations of the Office of Programming, Georgia State Department of Transportation, and the Department of Industrial and Systems Engineering, Georgia Institute of Technology, through the Georgia Governor's Intern Program.

Definition of The Problem

A total of over 200 million dollars was spent in fiscal year 1972 for highway improvements in the State of Georgia. This amount, though large, cannot begin to fill the 10 billion dollars* in estimated highway needs for the years 1970-1990. This clearly indicates that the availability of financial resources falls far short of the amount of need. This scarcity of financial resources necessitates that improvements be considered as investments competing for limited resources. It is, therefore, necessary to establish priorities to the improvement projects so that programs may be selected to satisfy the most critical needs and make maximum

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*The 1972 National Transportation Report gives the figures of highway needs, 1970-1990, for the State of Georgia to be 10,251,900,000 dollars while the overall transportation needs of the state are 12,267,500,000 dollars.

effective use of the available resources while still meeting the budgetary constraints.

Today in the State of Georgia, transportation improvement projects are first screened and evaluated by the Office of Planning, and then channeled to the Office of Programming to be programmed and scheduled for design and construction. Priorities are then assigned to these improvements largely on the basis of experience. Priorities that are established subjectively may sometimes be biased because of personal engineering bias and lack of comprehensiveness. Furthermore, the lack of consistency and high susceptibility to external pressure are also some drawbacks to subjective priority analysis.

The increasing number, magnitude, and complexity of the highway programs will soon make subjective priority analysis unmanageable. The problem is further complicated with the emergence of multi-modal transportation, which demands that highway programs be coordinated with programs of other modes of transportation. Furthermore, the recent upsurge of public interest in socioeconomic and environmental consequences of highway improvements has caused a dramatic modification in the planning process with more extensive considerations given to these factors. It follows that in addition to needs and deficiencies, the socioeconomic and environmental consequences must also be considered in the priority analysis process.

It is, therefore, essential to have a comprehensive and systematic procedure for establishing priorities. A priority setting procedure will serve not only as a management tool for project programming and scheduling, but as an aid for the State Transportation Board and Department administrators in their decision-making process. Effective decision making will enable the Department to better manage its programs, with an overall view towards ensuring better use of the Department's resources.

Objective and Scope

The objective of this research is to develop a procedure for ranking transportation improvement projects on a comprehensive and objective basis. The procedure is designed so that it:

1. May be implemented in the immediate future without extensive changes in the existing data system and planning process;
2. Incorporates economic, social, and environmental factors in addition to other appropriate factors;
3. May accept both state and local inputs;
4. May be programmed for electronic data processing; and
5. May be extended to include multi-modal transportation improvements.

The procedure will initially be highway-oriented since improvement projects in other modes of transportation are very few in number at the present time. Moreover, other modes of transportation have separate funding sources which render priority analysis unnecessary for the near future.

The scope of the research includes:

A. An extensive literature search of the programming process and priority analysis procedures presently in use by other states and urban areas;

B. Identification of appropriate parameters for evaluation of improvement projects in the priority analysis procedure.

C. Examination of the existing data system and planning process in the Georgia State Department of Transportation for data availability;

D. An analysis of the available techniques for project selection; and

E. Development of the priority analysis procedure, either by modifications of an existing procedure, or through application of an operations research technique.

CHAPTER II

THE PROGRAMMING PROCESS

Programming, from the highway point of view, can be defined as: "The orderly process by which highway improvement projects are selected on a basis of factual need in accordance with established objectives and goals, and includes allocation of resources, project scheduling and program implementation."(1)

Highway programming can be visualized as the link between planning and operations, while being a part of each.(2) The planning phase carries out the tasks of gathering data, analyses, forecasting future demand, and incorporating decisions by top level management to arrive at long-range planning goals and plans. From these long-range goals and plans, programs are developed and balanced, based on available resources and other considerations. The operating units, following the program on a project-by-project basis, then carry out the work of conducting surveys, preparing designs and plans, acquiring right-of-way, and construction supervision, which eventually turns the planning goals into physical accomplishments.

Programming is by no means a newcomer in the transportation field. The fundamentals of programming have been practiced since the first road was built, perhaps not in a clear-cut and technical fashion, but at least on an intuitive and informal basis. As of today, every state and most urban areas have some form of programming for their highway improvements. However, the methods and procedures as well as the underlying objectives and principles vary widely as noted in a review:

> Objectives, principles, methods and procedures of program formulation and scheduling vary widely among the states . . . There are, of course, certain similarities among some states, but these are found to be more superficial than fundamental. Variations seem to be the result of differing state laws, basic objectives, administrative polpolicies and procedures, size and scope of programs, centralized vs decentralized operations, personal relations, and other factors, the combination of which defy simplification or standardization of exposition. (3)

Despite all these differences, the process of programming employed by most states is, conceptually, relatively simple and has been grouped under the heading of iterative process. (2) An alternative process - optimization - has been proposed, but still is in the development stage. The optimization process will be discussed briefly in Chapter III.

The iterative process starts with the task of assigning priorities to a set of unordered projects and formulating a program based on various considerations and constraints. Its end product is a shcedule of projects to be accomplished which is continuously monitored and updated until the final completion. The iterative process can be broken down into five main elements;

1. Priority analysis;
2. Program formulation;
3. Review, adjustment, and approval process;
4. Project scheduling; and
5. Program implementation

The inter-relationships between these elements are as shown in Figure 1.

Inputs

The programming process requires inputs from all levels of the

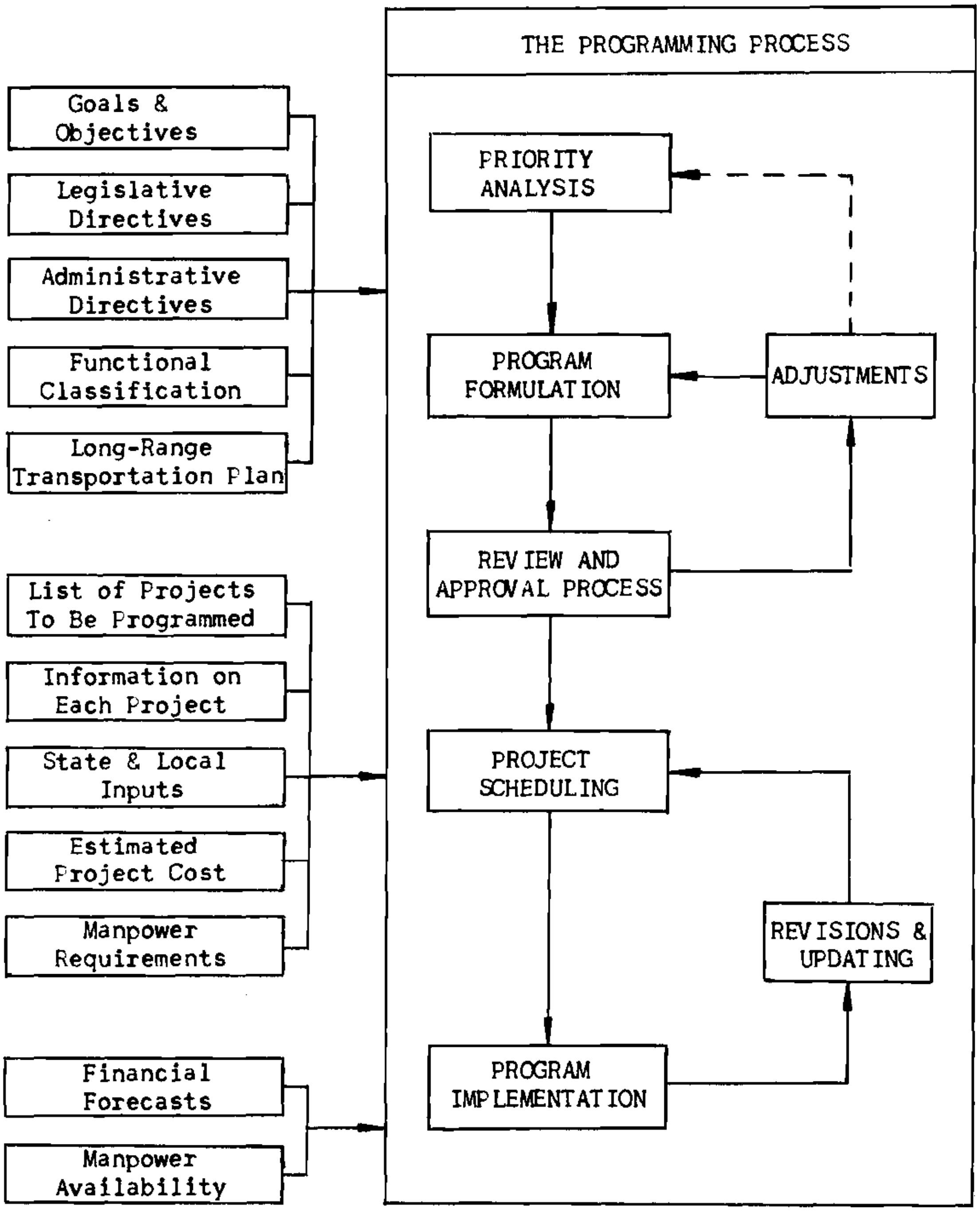


Figure 1. Schematic Diagram of the Programming Process

department. It starts with a list of unordered projects and related information about each project, from physical data to forecasted demand and consequences on communities. The process continues with details about financial and manpower requirements and availability. There are also other inputs that deal with the total system which provides the general directives that are often more important than the specific details. Figure 1 portrays the necessary inputs and their relationships with the various elements of the programming process.

It should be emphasized at this point that programming serves as a bridge between planning and operations, while being a part of both. The success, or failure, of the programming process depends not only on the procedure itself, but also on the confidence and support from all levels of the department. In a narrower context, it may be stated that the programming process is only as good as its inputs.

Objectives and Goals

Every department of transportation must have goals and objectives toward which all the productivity and work of the department are geared. The overall goals and objectives for the highway mode of transportation can be simply stated as:

1. To provide a good highway system which will serve its proper function in the overall transportation system;
2. To provide optimum utilization of resources;
3. To select highway improvements based on objective priorities; and
4. To assure that the best interests of the public are served.(1)

These goals and objectives are too broad and vague to provide any specific directives. However, these are the goals against which programs and projects should be tested.

Legislative Directives

System priorities established at the top level of decision-making steer the general direction of the transportation system while leaving enough latitude for the department administrators to manage the details of the program. The degree of legislative involvement varies between states from almost total control of the detailed highway program to only general responsibility for policy. It is discussed in a workshop for highway officials that the legislative directives should be to:

1. Establish highway development policy;
2. Define state responsibility;
3. Provide funding for the highway program;
4. Allocate funds to specific programs and jurisdictions; and
5. Indicate criteria for program development.(1)

Long-Range Transportation Plan

A long-range transportation plan usually spans a period of 15 to 20 years and provides the directives for the department within that period. The long-range plan identifies the objectives for development, perhaps even identifying priorities among systems. However, the long-range plan is usually not detailed as to specific projects. The importance of a comprehensive long-range transportation plan can be exemplified from the following remark by a highway official: ". . . the most important legislative constraint is the presence or absence of a long-range plan of improvements which has been adopted by the legislature with the full participation and support of local county and municipal governments and the people."(1)

Functional Classification

The Federal-Aid Highway Act of 1968 initiates a program on the functional classification of the highway system. This enables the programming process to define objectives, allocate funds on a priority basis, and set construction programs for each category of highway separately. A highway official commented on the importance of highway classification:

> The classification process provides a rational method of segregating the total road network into manageable units to properly allocate jurisdictional, financial, administrative, construction, and maintenance responsibilities, and to assign these responsibilities to the appropriate unit of government.(1)

List of Projects

After the general directive inputs, the fundamental specific input is a set of unordered projects to be selected and programmed. Figure 2 shows the various sources of the projects which consist of:

1. Proposed new projects;
2. Previously proposed, but not programmed projects; and
3. Previously programmed projects, both active and inactive.

All these projects are assumed to be 'justifiable'. In other words, these projects have already been screened for justification and best alternatives by the planning units. The sources of new projects include:

1. Long-range transportation plan;
2. Transportation studies, such as needs, safety and traffic engineering; and
3. Other sources. For example, county commissions, regional

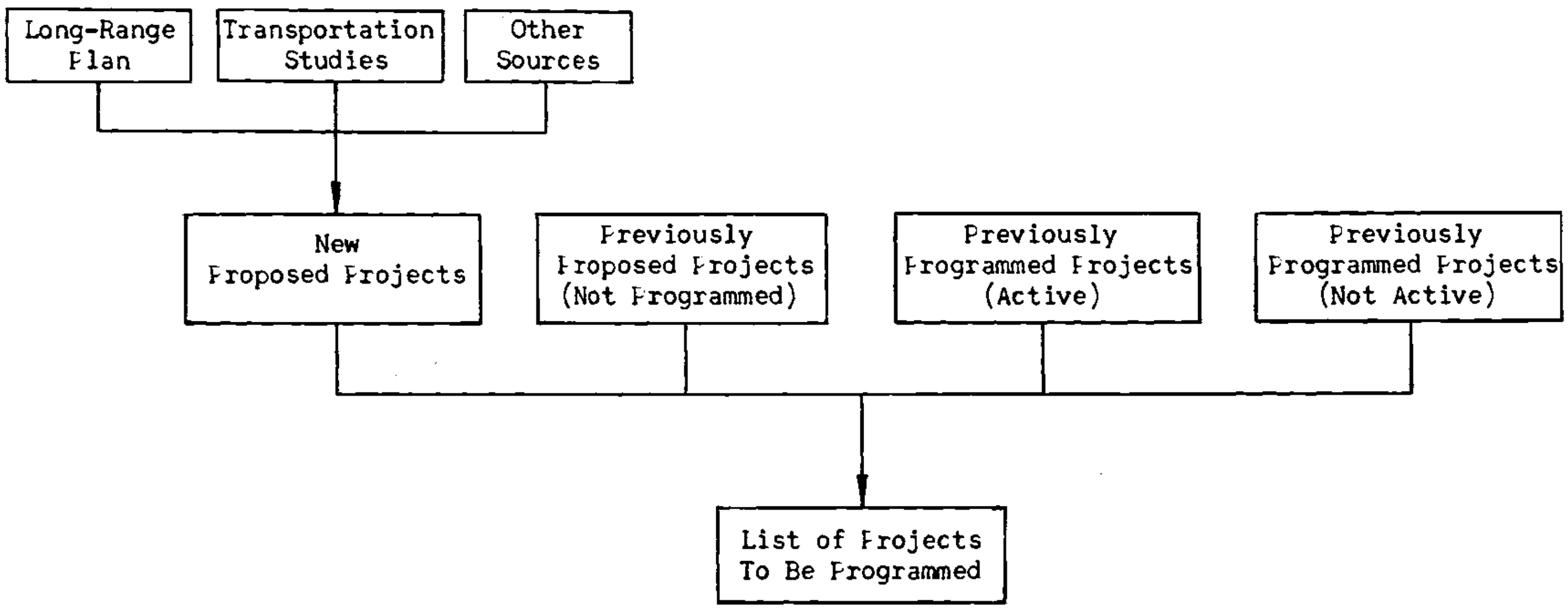


Figure 2. Schematic Diagram Showing Project Sources

planning and development commissions, citizen's requests, etc.

Related Information on Projects

To properly evaluate and compare the projects, some or all of the following information is necessary for each project:

1. Some indication as to the degree of need for the project;
2. Physical inventories which are compared to desired standards for determining deficiencies;
3. Economic analysis;
4. Route continuity and coordination with other improvements; and
5. Socioeconomic and environmental consequences.

A detailed discussion on these factors will be presented in Chapter IV.

State and Local Inputs

Even with all the related information about the projects, there is still a human element that must be taken into consideration. This human element is in the form of:

1. Political inputs from state and local officials, for example, county commissioner priority lists; and
2. Local opinions from hearings, newspaper editorials, and requests or complaints from local civic groups and individuals.

There is a gradual trend of more public involvement in the planning and programming phases of highway improvement proposals, as noted by a highway official: "The public should be brought into the planning and programming activity early in the process. Administrators and planners should sit down and talk to the people." (1)

Cost Estimates

The cost estimate for each project must be provided and be as accurate as the situation permits. The estimates should also be broken down into stages, such as preliminary engineering, design, right-of-way, structures, construction, etc., to provide more details and accuracy, both in program formulation and scheduling. It is conceivable that substantial errors may exist in the estimates. However, a little more effort in the process of estimation will minimize time-consuming changes and may lead to more efficient use of the available resources.

Financial and Manpower Resources

Reasonably predictable revenues are essential to effective highway programming. Since state highway funds are mainly derived from state gasoline taxes, motor vehicle registration fees, tolls, bonds, and the states' general funds, it is usually fairly predictable although the allocation for the highway program depends on the attitude of the legislature and the public. The availability with Federal funding is less predictable and this is a major influence on the states' programs. The administrators must therefore anticipate the possible changes in Federal revenues to provide as accurate a forecast of revenues as humanly possible.

The availability of manpower also plays a major role in the programming process. It goes without saying that the program and schedule must be so formulated as to make the most effective use of the available manpower by leveling the work. There is, however, a tendency in most states to adjust their manpower to suit the workload as dictated by the highway program.

Priority Analysis

Since the need for highway improvements is always greater than the available resources, the projects must be evaluated and compared to each other while competing for those resources. Priority can therefore be defined as the systematic process of ranking the projects according to certain criteria to measure their relative degree of need, deficiency, and desirability.

A 1970 survey (4) shows that 90 percent of the states are using some form of sufficiency rating as their main criteria in priority analysis. Some states have very well developed procedures using sufficiency ratings while others are using it as a guide or indicator for the degree of urgency. Economic analysis is also often used in priority analysis, the prime example being Pennsylvania which uses internal rate of return to rank the projects. (10-24)

Criteria used in priority analysis vary widely among the states as evidenced from the large number of information sources listed by the 1970 survey. (4) In the replies to the question "What information does the state have to assist in making priority analysis?", 33 items are identified as shown in the following information in descending order of the number of times each was mentioned:

1. Sufficiency ratings
2. Needs studies
3. Safety studies
4. Long-range highway plans
5. Traffic studies
6. Urban transportation studies
7. Route continuity
8. Functional classification
9. Physical inventory
10. Fiscal resource studies
11. Estimated cost
12. Geographical location
13. County commission priorities
14. Economic development
15. Requests from citizen groups
16. Road life
17. Administrations and political commitment
18. Benefit/cost ratio

19. Land use
20. Maintenance cost
21. Water resource studies
22. Water transportation studies
23. Mass transit studies
24. Recreational studies
25. Capacity deficiency
26. Time of functional obsolescence
27. Corridor study priority
28. Public demand
29. Trip length
30. KIP factor
31. National airport plan
32. Lead time required
33. Federal-Aid regulations

Over the years, many methods and procedures have been developed for priority analysis. Several representative procedures will be examined in Chapter III. Whichever procedure is used or whatever information is considered, the end product is a list of projects ranked in order of certain criteria, such as need, deficiency, urgency or desirability.

Program Formulation

Highway programs are usually formulated in two different time spans: the long-range program and the short-range program. The long-range program spans 15 to 20 and the general directives within that period. The program is usually not detailed as to specific projects.

The short-range program covers a period of 5 to 6 years and includes specific projects, or part of projects to be completed during particular phases of the program period. The program formulation is based on the following inputs, as shown in Figure 1:

1. A list of ranked projects;
2. Cost estimates of each project;
3. Available funding during the program period;
4. Legislative or administrative directives as to the allocation of funds by; a) administrative jurisdictions, b) func-

tional classification systems, and c) type of improvement.

5. Long-range program.

The basic objective of program formulation is to select projects from the priority list that will meet the legislative and administrative constraints, preserve as much of the priority order as possible, and make maximum effective use of the available resources, mainly financial. There are also other considerations that will enter into the formulation process, such as political commitments, coordination with adjacent states, etc.

The program formualtion process is a highly complex process which requires a lot of subjective judgement on the part of the middle level decision-makers. However, the complexity of the process makes pure subjective judgements prohibitive. The ideal program formulation process should therefore be based on a comprehensive, systematic, and defensible procedure, controlled and monitored by subjective judgements.

Review, Adjustment, & Approval Process

After the initial program formulation, the program will be reviewed by the appropriate administrators, on the state and/or local levels, adjustments will be made to the program until it is satisfactory to all parties or a compromise is reached for final approval. The program will then be scheduled for implementation.

This review, adjustment, and approval process is basically a political bargaining process based on subjective judgements and interests. There is, of course, the always present possibility of biased or misjudged political pressures which fail to base their decisions on the ultimate accomplishment of the established goals and objectives or on the maximum effective use of the available resources. On the other hand, some have argued that the political bargaining process is not as bad as it may seem. If the decision-makers are provided with comprehensive, appropriate and unbiased facts and information, they can usually make 'good' decisions.

This argument is based on the fact that political pressures, in most instances, are aimed at serving the interest of certain communities or interest groups. In other words, the political pressure indicates what the communities or interest groups want in terms of transportation. This in turn often reflects what the general public in certain locality or region want. These pressures are frequently not for the overall statewide interest. This unavoidably will create conflicts between local and state and/or local interests. The most effective way to settle such conflicts is through the powers of political bargaining. The end product should be a comprise between state and local interests which ultimately serves the general public's interests.

The key issue here is that the initial program formulation should be based on a comprehensive, systematic as well as defensible procedure, which should have the confidence and support of the top level decision-makers. Furthermore, the procedure should be able to provide the decision-makers with complete and unbiased information in case of any changes. This will ensure a minimum amount of modifications to the program and if such changes are necessary, the decision is based on comprehensive and unbiased facts.

Project Scheduling

Scheduling is defined as the process of developing a plan of operations to carry out the program. The process involves breaking down projects into activities, setting starting and ending times for those activities, determining the resources required to do the work, then adjusting the times as necessary to balance the resource requirements. Other considerations such as letting dates, contract sizes, seasonal conditions, cash flow and legal considerations must also be taken into account in scheduling.

Scheduling is the best developed segment of the programming process, partly because it is directly related to operation management and partly because it involves mostly mechanical details which require relatively fewer subjective judgements. Electronic data processing with increasingly sophisticated techniques to aid in scheduling and updating are widely used as compared to only 10 percent of the states using electronic data processing (4) in their priority analysis and program formulation phases.

The actual scheduling operation begins after the program is approved. The projects are grouped into successive yearly intervals such that the estimated total project costs are balanced with the revenues and represents a reasonably uniform workload. There are considerable differences among the states as to what schedules are best suited to their particular situations. However, three schedules of varying details are often prepared for the different levels of administration. (5)

1. The long-range schedule, extending up to 10 to 20 years, provides a complete plan for attaining the goals of the long-range plan. A long-range schedule is primarily for the use of top management and

shows beginning and ending times on an annual or semiannual basis for the major function of each project - engineering, right-of-way acquisition, and construction. Through these schedules top management can assure the most effective use of monies, manpower, and other resources.

2. The intermediate-range schedule, extending five to six years, should include all work for which a firm plan has been made. An intermediate-range schedule is primarily for the use of middle management, which comprises the heads of the major operating divisions and districts. This schedule should provide the middle management with a tool to monitor their own activities as well as furnishing a means to determine the future manpower and other resource requirements for their area of responsibility.

3. The short-range schedule, spanning one to two years, is primarily for the use of operating management, including detailed project schedules for each job that is underway or is to begin in the immediate year. The project schedule is thus the most detailed of all the schedules and should be directed at establishing firm contract letting dates.

Program Implementation

After scheduling, each phase of a project is assigned to the appropriate operating division for implementation. To insure that the program proceeds on schedule as nearly as possible, project progress is monitored. This is done by periodic checks by the programming office, or is provided by the responsible operating divisions. Progress reports are routinely prepared at specific times for all projects and for special purposes on request. It is each operating unit's responsibility to conduct its phase of the project and advise the program engineer of its status. It is the program engineer's responsibility to evaluate progress, interrelations among many projects and goals, and to recommend appropriate revisions. It is the administrator's responsibility to decide what course of action will be followed.

When serious delays occur in any project or program, the schedule must be re-evaluated and revised to make the best use of the available resources. Tying up money and manpower, or both, on projects which are not progressing overall should be avoided whenever possible. There is also a need to be prepared for emergency situations, such as a fallen bridge or severe flood damage. Political pressure is another maker of emergency projects, although a defensible and good programming procedure will tend to minimize this situation. However, it is impossible to anticipate natural disaster and the programming process should be able to cope effectively with this situation which may require extensive reprogramming.

In addition to revising schedules, there is usually a continuous updating process to monitor current project status. This is needed to coordinate other related operations that are dependent on completion of a phase or all of the given project. The updating also advises management on the current status of projects, funds, and manpower, and aids in foreseeing problems.

The Current Situation in Georgia

The present programming process in the Georgia State Department of Transportation is basically similar to the iterative process described above. Figure 3 illustrates the various components for the development of a six-year highway program in the State of Georgia.

Legislative directives and constraints on the development of the highway programs are minimal. The Georgia Code of Public Transportation, (26) as approved by the Legislature, does provide some very broad guidelines, but essentially leaves the Department administrators to set up their own directives.

The prime financial resources for the Department are state gasoline taxes and bond sales, though appropriations from the State's general budget may be requested for special programs. These resources, coupled with Federal-aid funds, constitute the financial base of the Department. Forecasts of revenues are then projected by the Accounting Office for program development.

The State Transportation Board is in charge of the final approval of the highway programs. The only established guideline for program formulation is that 70 percent of the Department's highway construction funds will be divided equally among the ten Congressional Districts in the State.

The remaining 30 percent is then allocated on the basis of need. There are no existing policies on the allocation of funds to the various highway functional classes and types of work, and the distribution of Federal-aid funding becomes a prime determining factor.

At present, the functions of program formulation, project scheduling, and program implementation are not inter-related in a satisfactory way, and hopefully, the recent installation of the Multiproject Programming and Scheduling System (MP/SS) will be able to provide the necessary coordination.

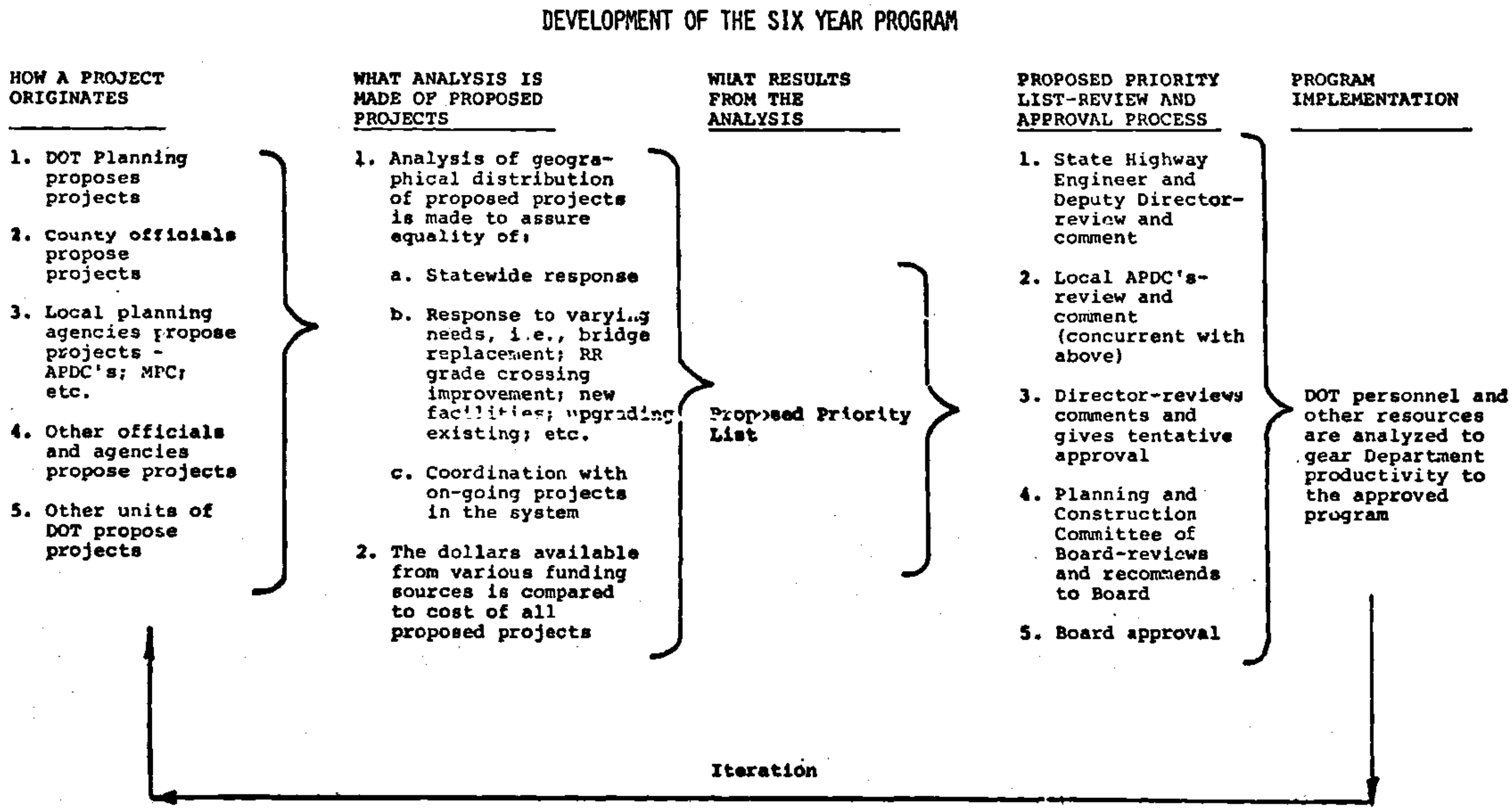


Figure 3. Programming Process in the Georgia Department of Transportation

CHAPTER III

PRIORITY ANALYSIS

Priority analysis is defined as the systematic process of ranking improvement projects according to certain criteria which measure their relative degree of need, urgency, or desirability. Over the years, many methods and procedures have been developed for priority analysis (8-25), most of which based on some form of sufficiency or deficiency rating. Conceptually, these procedures all consist of:

1. A rating system to establish the relative degree of need, deficiency, or desirability of the projects. The criteria used in the rating system are based on certain quantitative and/or qualitative factors about the projects.

2. The projects are then ranked based on their ratings and/or other qualitative inputs.

However, the similarities between the procedures end at this point and any further generalization of the process is considered to be unadviseable.

Existing Priority Analysis Procedures

Some of the better developed procedures are described briefly in this section, followed by some general comments on these procedures. The procedures discussed in this chapter include:

a. Five states - Arizona, Pennsylvania, Tennessee, Washington, and Wisconsin;

b. Three urban areas - Nashville, Tennessee; Phoenix, Arizona; and San Diego, California; and

c. A procedure recommended by the National Association of County Engineers.

A new methodology using the optimization process, proposed for use by the Ontario Ministry of Transportation and Communications, Canada, is also presented to illustrate the alternative to iterative process - Optimization.

Arizona (11)

The priority analysis procedure employed by the Arizona Highway Department is basically an extension of the sufficiency rating system. Projects are evaluated for their priority ratings which is a combination of two sets of ratings.

The first set of ratings is the familiar sufficiency rating which is essentially "an inventory of what a road is and what it does, compared to geometric standards of what it should be to satisfactorily and safely carry the traffic that uses the facility, now and over its expected material life span" (11). One hundred points are broken down into three major headings: (i) condition, 35 points, (ii) safety, 30 points, and (iii) service, 35 points. These broad categories are further subdivided as follows:

Condition		35 points
Structural adequacy	17	
Remaining life	13	
Maintenance	5	
Safety		30
Roadway width	8	
Surface width	7	
Sight distance	10	
Consistency	5	

Service		35
Alignment	12	
Passing opportunity	8	
Surface width	5	
Ride quality	10	
	Subtotal	100 points

The second set of ratings attempts to take socioeconomic and environmental factors into consideration. Again, one hundred points are broken down into three major headings: (i) environment, 40 points, (ii) economic development, 35 points, and (iii) traffic safety, 25 points. The environment category is further subdivided into:

Environment		40
Pollution	15	
Resources	12	
Aesthetics	8	
Recreation	5	
Economic Development		35
Traffic Safety		25
	Subtotal	100 points

This is one of the initial attempts to incorporate socioeconomic and environmental factors into the priority analysis. Admittedly, these qualitative factors are loosely defined and based solely on subjective judgements. However, this is definitely a step in the right direction.

The sufficiency rating is first adjusted for traffic volume and then added to the socioeconomic ratings to give the final priority rating. Improvement projects are first rated and then tabulated in numerical order by functional systems. The first year's program will go from the rated section on the list to the point where funds are depleted.

Pennsylvania (20-21)

The Pennsylvania Department of Transportation uses an analytical procedure significantly different from others which employ some form of sufficiency or deficiency ratings. The Pennsylvania procedure is based on a form of economic anlaysis - rate of return.

The procedure starts with the forecast of: a) the calendar year of structural retirement or obsolescence of the highway by calculating the life expectancy from road life curves, empirically adjusted for traffic and truck volumes; and b) the calendar year of functional obsolescence which is defined as the year in which expected traffic volume equals the capacity of the highway at a desired level of speed. These two critical years do not necessarily coincide and any coincidence is actually accidental.

When structural obsolescence occurs prior to functional obsolescence, the year of improvement is the year of structural obsolescence. Should the functional obsolescence year precede the structural obsolescence year, a choice exists: to do nothing and allow congestion to pyramid until the structural obsolescence date, or to improve the highway immediately to alleviate congestion at the year of functional obsolescence, possibly sacrificing the residual structural life.

To analyze the various alternatives as to the optimum time and optimum type of improvement, the congestion delay cost is calculated. Congestion delay is determined as the difference in time between the desired speed, and the speed as reduced by the excessive volume of traffic using the highway. Congestion delay cost is then estimated by translating congestion delay time by some acceptable value of time.

The best alternative is pinpointed by calculating the approximate rate of return and the incremental rate of return. The approximate return is given by

$$RR^{X-N} = \frac{AUC^X - AUC^N + AMC^X - AMC^N}{cc^X - cc^N}$$

where RR = Approximate rate of return
AUC = Annual user cost (congestion),
AMC = Annual maintenance cost,
cc = Present worth first construction cost,
X = Alternative X,
N = Null alternative (Do nothing), and
X-N = Alternative X compared to the null alternative

while the incremental rate of return is given by

$$rr^{Z-X} = \frac{AUC^X - AUC^Z + AMC^Z - AMC^X}{cc^Z - cc^X}$$

where rr = Incremental rate of return,
Z = Alternative Z, and
Z-X = Alternative Z compared to previous acceptable Alternative X.

The minimum attractive rate of return is set at 20 percent. In other words, any alternative with an approximate or incremental rate of return of less than 20 percent is unacceptable.

By sorting improvement within calendar years, a priority list can be established, first of those projects structurally obsolete, then of the functionally obsolete projects, listed in descending values of their rate of return. A program can then be developed by going down the list until the available funds are exhausted. Projects that cannot be accomplished in one fiscal year will be carried over to the next fiscal year.

Tennessee (16-17)

Tennessee is one of the first states to develop a systematic priority analysis procedure. A three-digit priority index is used to rate the highway sections in terms of structural condition, facility of movement, and safety for rural highways and condition, congestion, and route characteristics for urban highways.

For rural highways, the first digit signifies the structural condition of the highway which is broken down into:

Surface		50 points
Base and subbase		30
Drainage		10
Subgrade		10
	Total	100 points

The second digit appraises a section of facility of movement. Deficiency of movement in hours of low traffic and of maximum traffic is obtained by subtracting actual average design speed from standard design speed and actual operating speed from standard operating speed. The average of the two differences is then multiplied by the average daily traffic to give an index which indicates the section's weighted deficiency in facility of movement. The last digit denotes a measure of traffic safety which is expressed by the number of accidents per mile.

Each of the three sets of ratings are then arranged in descending order of magnitude and divided into 10 groups with numerical designations of 0 to 9 indicating increasing degrees of deficiency. Each section is thus rated by this three-digit priority index.

The rated sections are then grouped into five successive arrays in order of their urgency:

Array 1: Structural condition ratings of 9, 8 and 7 arranged in that order. Each of these groups of like appraised structural deficiency is further arrayed according to the facility of movement ratings and, then to their safety ratings.

Array 2: Facility of movement ratings of 9, 8 and 7 in that order. Sections in each of these groups of like deficient facility of movement are further arrayed according to their structural condition ratings and, then, to their safety ratings.

Array 3: Safety ratings of 9, 8 and 7 arranged in descending order and then further arrayed according to their structural and facility of movement ratings.

Array 4 Structural condition ratings of 6 and 5 and arrayed according to their facility of movement and then to their safety ratings.

Array 5: The remaining sections in order of their facility of movement ratings and then arranging them in order of their structural condition ratings and their safety ratings.

The priority rating process for urban highways is very similar to that of rural highways in which a 3-digit priority index is used to rate the sections which are then grouped into 4 arrays in order of their urgency.

The first digit of the priority index for urban highways denotes the condition of the highway either as 0, acceptable, or as 9, needing improvement. The second digit is a measure of congestion which is analogous to facility of movement for rural highway. The congestion rating is expressed in terms of number of vehicle-miles inconvenienced and rated sections are then assigned congestion indices 0 to 9 according to the indicated absence or degree of congestion.

A factor called 'route characteristics' comprises the third digit of the priority index, substituting for the safety factor employed for rural sections. Route characteristics include a number of dimensional features of the roadway cross-section and certain features of alignment and development as follows:

Lane width	50 points
Bad curves	10
Offset in alignment	10
Wandering alignment	10
Right angle turns	10
Rural cross-section where urban cross-section is needed	50
Mainline railroad grade crossing	50
Restricted clearance, both horizontal and vertical	50

Again, the sections rated for route characteristics are then divided into 10 groups based on their deficiency score. The groups are designated 0 to 9, depending on the absence or degree of deficiency.

The rated sections are grouped into four successive arrays in the order of their urgency similar to the rural situation except for different emphasis on factors.

Array 1: Congestion ratings of 9, 8, 7, 6, and 5, grouped in that order. Each group is then further arrayed according to its condition rating and then to its route characteristics rating.

Array 2: Sections rated 9 for condition are arrayed according to their ratings for congestion and route characteristics.

Array 3: Route characteristics ratings of 9, 8, 7, and 6, arranged in that order. These groups are then further arrayed according to their congestion ratings.

Array 4: All remaining sections arrayed in order of their congestion ratings and then their route characteristics ratings.

The priority lists are then field checked for their practical validity. A program is then developed based on these priority lists, but with careful consideration for other factors requiring subjective judgements.

Washington (13-15)

The Washington Department of Highways is one of the several states required by legislative statute to establish a policy of priority programming. Functional classification of the highway system is mandatory and priorities are established for each functional class.

The following criteria is given consideration in developing priorities for the highway sections:

1. Structural condition - Its structural ability to carry loads upon it. A rating of zero to 100 is used for rating the pavement condition. the structural condition of bridges, tunnels, and other structures is measured by the remaining life before remedial work or replacement is necessary.

2. Congestion - Its capacity to move traffic at reasonable speeds without undue congestion. The traffic volume to capacity ratio is used as the indicator for degree of congestion.

3. Alignment and related geometrics - Its adequacy of alignment and related geometrics. The following items are considered:

    a. Horizontal curves
    b. Bridges
        Vertical clearance
        Roadway width
    c. Pavement width
    d. Roadway width
    e. Stopping sight distance

    Acceptable conditions are established for each item and each functional class. The measured values of each item are then compared with the acceptable standards and the appropriate degree of adequacy is thus determined.

4. Accident experience - Its accident experience and its fatal accident experience. Hazardous accident locations are identified by examining the number of accidents per million vehicles for spots and intersections and accidents per million vehicle-miles for sections.

5. Economic analysis of designated but unconstructed highways - In the case of designated but unconstructed highways, its economic importance measured by a cost-benefit analysis, the effect on the state's economy, and benefit to the geographical area concerned. A proposed route index is used for this purpose.

After evaluating the projects based on these factors, the projects are then placed into the 18 priority groups according to their extent of deficiency or urgency. Table 1 shows the 18 priority groups with their criteria values. Once the analyses have been completed for all the proposed projects, they are then tabulated in priority order as shown in Table 2. Each project is then reviewed in light of the various priority criteria and an improvement will be proposed which will correct the criterical deficiency and also give cognizance to other lesser deficiencies.

<u>Wisconsin</u> (<u>12</u>)

Wisconsin Department of Transportation recently devised a priority analysis procedure for its long-range planning study of rural arterial highways. This procedure was developed with due considerations for electronic data processing which unfortunately has been used by less than 10 percent of the states in their priority analyses. (<u>4</u>)

The Wisconsin procedure uses four indicators of highway needs:

Structural adequacy		40 points
Surface condition	25	
Roadway ditches	5	
Maintainability	10	
Service		30
Rideability	5	
Alignment	12	
Surface width	5	
Non-passing zones	8	

Table 1. Priority Groups & Priority Parameters, Washington Department of Highways

PRIORITY GROUP NUMBER DETERMINATION 5-15-70

PRIOR. GROUP NO.	ITEM	RADIUS	R OR U	TRAFFIC	NO. OF LANES	INTERSTATE RATING	INTERSTATE STD.	PRINCIPAL RATING	PRINCIPAL STD.	MAJOR RATING	MAJOR STD.	COLLECTOR RATING	COLLECTOR STD.	OTHER RATING	OTHER STD.
						RANGE OF RATING VALUES									
1	BRIDGE CONDITION - L.E.		-	-	-	< 1978	-	< 1978	-	< 1978	-	< 1978	-	< 1978	-
2	PAVEMENT CONDITION		-	-	-	< 45	-	< 37	-	< 37	-	< 36	-	< 32	-
3	HAZ. ACCID. LOC. INDEX ANALYSIS SECTIONS		-	-	-	> 0.6	-	> 0.7	-	> 0.8	-	> 1.2	-	> 0.4	-
	SPOTS/INTERSECTIONS		-	-	-	> 1.5	-	> 1.6	-	> 1.5	-	> 1.5	-	> 2.1	-
4	VOLUME/CAPACITY		-	-	-	> 0.50	-	> 0.90	-	> 0.90	-	> 0.90	-	> 1.00	-
5	HORIZONTAL CURVES	< 940'	R	-	-	> 0	0.6								
		< 600'	U	-	-	> 0	0.5								
		< 760'	R	-	-			> 0	1.5						
		< 460'	U	-	-			> 0	1.0						
		< 600'	R	-	-					> 0	2.0				
		< 350'	U	-	-					> 0	1.5				
		< 160'	R	-	-							> 0	2.3		
		< 250'	U	-	-							> 0	0.9		
		< 350'	R	-	-									> 0	2.7
		< 165'	U	-	-									> 0	1.0
6	PAVEMENT CONDITION		-	-	-	45-48	-	37-46	-	37-43	-	36-40	-	32-37	-
7	PROPOSED ROUTE INDEX		-	-	-	> 100	-	> 100	-	> 100	-	> 100	-	> 100	-
8	BRIDGES - VERT. CLEAR.		-	-	-	< 0	14.3'	< 0	14.3'	< 0	14.0'	< 0	13.8'	< 0	13.8'
9	BRIDGES - POSTED		-	-	-	All	-	All	-	All	-	All	-	All	-
10	PAVEMENT WIDTH		U	-	2	< 0	34'	< 0	34'	< 0	30'	< 0	28'	< 0	28'
			U	-	4	< 0	54'	< 0	54'	< 0	52'	< 0	50'	< 0	48'
			R	-	2	< 0	20'	< 0	20'	< 0	20'	< 0	18'	< 0	18'
			R	-	4	< 0	40'	< 0	40'	< 0	40'	< 0	40'	< 0	40'
11	BRIDGES - RDWY. WIDTH		-	-	2	< 0	22'	< 0	22'	< 0	20'	< 0	19'	< 0	19'
			-	-	4	< 0	42'	< 0	42'	< 0	40'	< 0	40'	< 0	40'
12	VOLUME/CAPACITY		-	-	-	0.71-0.90	-	0.71-0.90	-	0.71-0.90	-	0.71-0.90	-	0.71-1.00	-
13	STOP. SIGHT DIST. 0-474'		-	> 1000	-	> 6%	-	> 19%	-						
	0-474'		-	> 800	-					> 21%	-				
	0-349'		-	> 600	-							> 19%	-		
	0-349'		-	> 400	-									> 9%	-
14	ROADWAY WIDTH		R	-	2	< 0	28'	< 0	28'	< 0	26'	< 0	24'	< 0	24'
			R	-	4	< 0	48'	< 0	48'	< 0	48'	< 0	48'	< 0	46'
15	PAVEMENT CONDITION		-	-	-	49-53	-	47-50	-	44-47	-	41-42	-	38-40	-
16	PAVEMENT CONDITION		-	-	-	54-58	-	51-55	-	48-51	-	43-46	-	41-45	-
17	PAVEMENT CONDITION		-	-	-	59-100	-	56-100	-	52-100	-	47-100	-	46-100	0
18	PROPOSED ROUTE INDEX		-	-	-	0-100	-	0-100	-	0-100	-	0-100	-	0-100	-

Table 2. Sample Priority Array, Washington Department of Highways

P-52130

1 9 7 0 P R I O R I T Y A R R A Y

DISTRICT NO 2 ANALYSIS UNIT COLLECTOR CLASS DATE 05/15/70

STATE ROUTE	MILE POST	TO	MILE POST	EXIST LENGTH	1968 ADT	R U	- - B R I D G E S - - LIFE EXP	POST	VERT CL DEV.	RDWY WIDTH DEV.	PAVT RATG	HAZ.ACC. LOCATION INDEX	VOL/ CAP	PAVT WIDTH DEV.	RDWY WIDTH DEV.	DEFIC CURVES /MILE DEV.	STOPPING ST DIST PCT DEF	PROPOSED ROUTE INDEX	PRIOR RANK
PRIORITY GROUP 1 BRIDGE CONDITION - LIFE EXPECT							**												
		DRY GULCH					173-4												
173	2.89					R	1972			5									1
		POT HOLES EAST CANAL					24-305												
24	77.08					R	1976			5									2
PRIORITY GROUP 2 PAVEMENT CONDITION											**								
		SR 151 TO SR 97 WYE																	
151	24.10	TO	25.35	1.25	365	R					29	0.0	0.04	2	0	-0.7	0		3
		CHUMSTICK ROAD TO PLAIN																	
209	8.75	TO	13.59	4.94	450	R					32	0.0	0.09	0	0	-2.3	0		4
		SR 2 TO CHUMSTICK CREEK ROAD																	
209	0.00	TO	8.75	8.75	467	R					34	0.0	0.10	0	0	-2.3	0		5
		COL RIVER PK NPS TO SR 97																	
151	22.21	TO	25.49	3.28	1,165	R					35	0.0	0.24	2	0	1.4	7		6
PRIORITY GROUP 3 HAZARDOUS ACCIDENT LOCATION												**							
		SR 243																	
24	44.08	TO	44.08	0.01	552	R						5.3							7
		CHELAN NCL TO SR97 IN CHELAN																	
150	7.46	TO	8.04	0.56	3,475	R					68	5.2	0.52	32	26	4.8	12		8
		0.6 MI NO OF MAPLE LANE																	
153	4.87	TO	4.97	0.10	900	R						4.6							9
		ELECTRIC CITY NCL TO GRAND COULEE ECL																	
155	23.88	TO	26.23	2.35	2,065	R					59	4.2	0.60	4	12	-2.3	3		10
		GRAND COULEE ECL																	
155	26.21	TO	26.23	0.02	2,065	R						1.9							11

Safety		30
Shoulder width	8	
Surface width	7	
Non-passing zones	10	
Accident rate	5	
Time of functional obsolescence		25 points

The time of functional obsolescence is calculated using a formula by Gardner (21):

$$X = 25 \frac{\log \frac{SV}{A}}{\log \frac{Y}{A}}$$

Where X = Time of functional obsolescence in years
SV = Service volume ADT (Average Daily Traffic)
A = 1965 ADT and
Y = 1990 ADT.

The values of all four indicators are first converted to a common base of 40 to give the indicators equal weights prior to further analysis. The projects are then evaluated using multiple objective analysis which basically assigns various weights to the indicators and ranks the projects accordingly. A weighted average ranking is calculated for each section and the sections are ranked in order of increasing weighted average ranking. Further details concerning this multiple objective analysis technique are given in the original publication. (12)

Based on the measured values of the four indicators, the type of improvement required for each section is determined. The sections are then divided into 5 groups, each for a 5-year period, thus forming the long-range program.

Urban Areas (22-24)

The need for a systematic priority analysis procedure is felt not only by the states, but also by cities and counties on a smaller scale. Several procedures have been developed for use by urban areas. These procedures generally take some form of sufficiency or deficiency rating system. Two such attempts are shown below.

San Diego, California. The San Diego Procedure was developed in the 1956 San Diego Transportation Study. Priorities to improvements are determined by means of a priority index which is defined as:

$$\text{Priority Index} = \frac{\text{Project cost per vehicle-mile}}{\text{Project Benefit Index}}$$

The project benefit index is determined by:

Community service			60 points
Pattern and continuity		15	
Coordinating and timing		15	
Roadbed condition		5	
Present capacity ratio		15	
Long range future service		10	
User benefits			40
Time saving - delay rate		10	
Present	5		
5-year future	5		
Duration of deficiency		5	
Distance saving of improvement		5	
Accident rate - 2 years		15	
Time to amortize investment		5	
		Total	100 points

The project cost includes right-of-way plus construction per vehicle for 10 years. The priority rating index is based on the expected improvement in deficient conditions. The projects are then arranged in order of increasing priority index values.

Nashville, Tennessee and Phoenix, Arizona. Based on the San Diego effort, the cities of Nashville and Phoenix jointly modified the formula to the so-called 'Formula D':

Delay rate per mile during peak hour		50 points
Collision Index 2 year accidents/mile + Accident rate/mile		15
Structural condition		15
Surface and base	5	
Drainage	10	
Traffic $\dfrac{\text{Present ADT}}{1{,}500} + \dfrac{\text{5 year future forecast ADT}}{\text{2 x Present ADT}}$		20
Total		100 points

The projects are then arranged in order of highest point values.

Counties (6)

The National Association of County Engineers recommends a priority analysis procedure to be used by counties in preparing their advance road programs. The procedure recommends priority ranking by functional class, using a priority rating which is a combination of a service rating and a condition rating.

For urban roadways, the service rating is simply the current ADT (average daily traffic), which applies to rural arterials and collectors as well. For rural local streets, the current traffic volume is usually too low to be measured accurately and are replaced by:

Service rating (Rural local streets)

Number of dwelling units/mile	80 points

Mail or school bus route		10 points
Connection with other routes		10
		100 points

The condition rating expresses the extent to which the road (or structure) is deficient. The total score of 100 points is apportioned among the items evaluated as shown below:

Condition rating (Urban roadways)

Geometric element		30 points
Useable surface width	30	
Structural and drainage elements		70
Surface riding quality	10	
Structural strength	40	
Drainage	20	
	Total	100 points

Adjust for volume/capacity index

Condition rating (Rural roadways)

Geometric elements		50 points
Surface width	20	
Shoulder width	10	
Average safety speed	20	
Structural and drainage elements		50
Surface riding quality	10	
Structural strength	20	
Drainage	20	
	Total	100 points

Condition rating (Structures)

Roadway width	20 points
Vertical clearance	5
Approach alignment	15
Load capacity	25
Structural condition	20

Waterway area		15
	Total	100 points

The service rating (relative importance) and the condition rating (relative deficiency) are then combined to form the final priority rating which is expressed by the following formula:

$$\text{Priority rating} = 0.2\,(\text{Service rating} + 40)^{1/4}\,(100 - \text{Condition rating})$$

The projects are then ranked in order of their priority index for each functional class.

Existing Priority Analysis Procedures - Comments and Critique

The seven priority analysis procedures cited in this chapter, though varying widely in details, follow the basic concepts of an iterative process. These procedures can be further divided into three groups:

1. Sufficiency rating - composite rating. A single composite score is calculated for each project and the projects are then ranked based on their scores. The procedures employed by Arizona, Wisconsin, the three urban areas, and the National Association of County Engineers all fall under this category;
2. Sufficiency rating - priority arraying. The projects are segregated into priority arrays or groups based on ratings of individual elements. Tennessee and Washington employ procedures of this form.
3. Economic analysis. The projects are ranked according to their economic importance, expressed by benefit-cost ratio or rate of return. The Pennsylvania procedure is a prime

example of this approach.

In evaluating these procedures, the following general guidelines must be taken into account:

1. Objectivity. Subjective judgements and opinions should be minimized so as to provide answers that can be defended.
2. Comprehensiveness. The procedure should be devised so as to permit the consideration of all projects.
3. Consistency. The selection of projects should be consistent between themselves and from year to year. (5)

All these seven procedures meet these guidelines with some degree of success. However, there is something more in the evaluation of the procedures that are not included in these guidelines.

A serious weakness in the sufficiency rating approach is that the rating or score of a project has no physical meaning by itself. It only indicates the relative degree of urgency, but not the magnitude of urgency. A decision-maker is more concerned about the differences between projects in terms of physical units, such as money, manpower and time. For example, two projects A and B, with scores of 70 and 65 respectively, can be interpreted only as project A being more critical than B, but no information is being offered on the absolute costs or benefits of each project nor on their differences.

The economic analysis approach does offer some insight into the benefits and costs accrued by the improvement projects, but then it fails to identify the sufficiency or criticality of the conditions. In a nutshell, sufficiency ratings measure the urgency for improvement whereas economic analysis measures the benefit or importance of the improvement. Unfortunately, projects with high degree of criticality may not be the projects with high economic importance while projects with good economic returns are not necessarily those with the most critical needs.

Another significant conceptual drawback of the sufficiency rating approach and, to a certain extent, the economic analysis approach as used by Pennsylvania is that the rating is based on the need or deficiency of the road sections themselves, but it is the improvement projects which are to be assigned priorities. For example, consider two safety improvement projects A and B with identical accident rates. The sufficiency rating approach will indicate that both projects have the same priority. Let us suppose that project A will reduce the accident rate by 20 percent while project B will reduce it by 50 percent. Clearly, project B is more desirable and should be assigned a higher priority than project A because of its greater reduction in accident rates. However, the sufficiency scores would be identical and the projects will be assigned the same priority.

The factors used in obtaining the sufficiency score are not independent measures and the sufficiency rating approach does not take into account this dependency. For example, an improvement project on the alignment and geometrics of a road section may increase the capacity and operating speed on that road section. High speed and capacity may in turn attract more traffic and lead to more congestion and higher accident rate.

This also points to another problem with regard to the two approaches for sufficiency rating - composite score and priority arraying.

An objection to the composite score is it inability to distinguish between cases with a high score in one element or with a low score in several elements. A composite score, for example, cannot distinguish between a road section with critical structural deficiency and no functional or safety deficiency and another section with moderate deficiency in all three elements. On the other hand, the priority arraying approach places all the weight on only one of the elements and fails to examine the overall situation.

Economic analysis, by considering benefits and costs of projects, does not have most of the shortcomings of the sufficiency rating approach. However, the economic analysis approach and the optimization process, which will be discussed in the next section, both suffer vital drawbacks that have prevented their widespread use. The key issues are the estimation and quantification of benefits.

Let us consider a safety improvement project as an example. The primary benefit from this project is evidently the reduction in number of accidents, but there are also other benefits, both positive and negative, that result from the project. Even if all these benefits and costs can be identified, a bigger obstacle lies in the quantification of the benefits to a common measure, usually in terms of dollars. For instance, 'What is the cost of one fatal accident?' and 'What is the value of twenty-five minutes of waiting time for other drivers due to an accident?'. There has been considerable research directed towards quantifying these intangible factors (44-47), but in the author's opinion, there is still much to be done.

Until the estimation and quantification of benefits and consequences can be established in a satisfactory way, the economic analysis approach and the optimization process will not be able to replace the sufficiency rating approach despite of the latter's many drawbacks.

Except in Arizona, socioeconomic and environmental aspects of highway improvement projects have been ignored in the priority analysis procedures. It is conceivable that these factors are neglected because they are intangible and require subjective judgements - a violation of the basic guideline of objectivity. However, the recent upsurge of emphasis on the social, economic, and environmental aspects of highway improvements dictates that at least equal weights be placed on these factors as compared to the traditional need, deficiency and service factors.

> . . . The socioeconomic aspects of highway projects are becoming more and more important in priority programming. Some people believe that highways should be used primarily as an economic development tool to revitalize depressed areas, such as Appalachia, by providing access and mobility to and within these areas. Others are of the opinion that urban highways should only be developed when they are designed to achieve broader urban goals, such as better housing, more beautiful communities, or better recreational and social opportunities. Highways do contribute in greater or lesser degree to such objectives, and so decision-makers are giving increased attention to such views, along with needs of the people for efficient motor vehicle transportation. (1)

Another factor that has gained considerable momentum recently is the increasing role of community participation in the planning process of highway improvements. This may be in the form of citizens advisory groups, local civic groups and even individuals who have organized to voice their opinions through public hearings, editorials, and direct contacts with the governmental agencies. A prime example is in new highway location studies which have been a focal point of controversy in many areas. Unfortunately, this aspect of local inputs has rarely been considered in the priority analysis procedures.

Optimization Process

The optimization process is conceptually quite different from the iterative process. In the optimization process, the functions of priority analysis, program formulation and project scheduling are all combined into one operation that produces the optimal schedule of available projects through the use of precise analytical techniques such as linear, quadratic, dynamic, and other forms of mathematical programming.

Linear programming is by far the most popular and most appropriate of these techniques. A linear programming model consists of three parts:

1. An objective function, which is a quantitative measure of effectiveness. It expresses in a single number the combination of properties contributing to the results. A typical objective function in programming may be to maximize the benefits accrued from an improvement project.
2. A set of constraints, which defines the feasible region within which acceptable answers may lie. The usual constraints encountered in the programming process are budgetary limitations, manpower availability, geographical distribution and distribution by functional class and type of improvement.
3. Means of providing an initial solution improving the solution systematically and knowing when the best or optimum solution has been reached. These techniques are well developed (51-52) and will not be further elaborated.

Although the concept of optimization in the programming process has been available for quite some time there has been relatively little effort in developing priority analysis procedure based on optimization. Only one attempt, to the author's knowledge, has been made to develop a methodology in priority analysis using the linear programming technique. That effort was made by the Ontario Ministry of Transportation and Communications, Canada. A brief description of this proposed methodology is presented in the following section.

Ontario, Canada (10)

The Ontario procedure is designed to derive priorities for both highway and transit improvements involving considerable capital expenditure, including:

A. New Highway construction

B. Improvements to highway right-of-way (re-alignments),

C. Highway upgrading (additional lanes, etc.),

D. Major reconstruction of highways,

E. Highway resurfacing,

F. Installation of major traffic control systems,

G. Replacement of structures,

H. Addition or replacement of transit equipment, and

I. New transit fixed facilities.

The following five categories of variables are being considered in the analysis:

1. Regional development Benefits:

   a. Employment opportunities - net change in wages due to improvement;

2. User benefits:

    a. Travel time - change in user's travel time due to the improvement;
    b. Vehicle operating costs - change in road user's vehicle operating costs due to improvement;
    c. Accident cost - change in accident cost due to improvement;
    d. Vehicle maintenance cost - change in automobile and truck vehicle maintenance costs due to improvement;
    e. Pavement roughness comfort - change in user comfort due to pavement surface improvements;
    f. Geometric design standard - change in user comfort cost due to change in geometric standard;
    g. Transit user cost - change in out-of-pocket cost of transit user other than vehicle operating cost due to improvement;
    h. Car ownership costs - changes in car ownership costs due to a transit improvement;
    i. Transit comfort-convenience - change due to improvement;
    j. Maintenance costs - change in road and/or transit maintenance costs due to improvement; and
    k. Transit operating costs - change due to improvement.

3. Social benefits:

    a. Community cohesion - net change in community cohesion due to improvement;
    b. Service sufficiency - change in shopping, cultural, etc., sufficiency of community due to improvement;
    c. Employment stability - change due to improvement;
    d. Community growth - change in growth rate due to improvement;
    e. Relocation hardship - social cost of moves due to acquisition of improvements right-of-way;
    f. Special landmarks - social cost of loss of special land marks due to improvement;
    g. Employment hardship - social cost of changes to the individuals unemployed due to the improvement;
    h. Public reaction - social cost of public reaction to the announcement of improvement; and
    i. Transit mobility - change in mobility for captive transit riders due to improvement.

4. Environmental Benefits:

    a. Noise - net change in number of people affected due to improvement;
    b. Air pollution - net change in number of people affected due to improvement;

c. Water pollution - net change due to improvement;
d. Natural land areas - loss of natural land area due to improvement;
e. Vibration - change due to improvement; and
f. View - net change in view due to the improvement.

5. Right-of-way:

Timing of right-of-way - change in costs due to timing of right-of-way acquisition.

Each factor, both tangible and intangible, is then quantified within the following framework.

Benefit or disbenefit = Quantity x Sensitivity x Cost,

where Quantity = A measure of the amount of change that takes place due to the introduction of an improvement;

Sensitivity = The relative sensitivity of the community concerned to the quantity of improvement impact;

Cost = The cost of preventing the impact, the replacement cost or a value judgement which would be subject to sensitivity analysis and revision by decision makers.

The benefits or disbenefits and costs accrued by an improvement project and strongly influenced by the timing of the project. Thus, these values are all discounted to the 'present worth' measure assuming a 20 year time horizon. An average or long-run interest rate is assumed for calculations of discounted values.

Several other assumptions are made for the methodology in addition to the 20 year time horizon and average interest rate. First, the list of candidate improvement projects for which priorities are desired, contains only legitimate improvements and not irrelevant alternatives. Second, for each of the 20 years in the planning period, estimates of the capital budget are available. Third, the capital budget must be completely exhausted during each period. Fourth, each improvement, once started, may be implemented over a number of time periods. Finally, provisions are made in the benefit and cost streams for future inflation.

Three different optimization techniques were studies and compared:

1. Benefit-cost ratio maximization. This technique is essentially a form of economic analysis whereby the candidate improvements are ranked in descending order by the ratio of present worth of benefits to the capital cost of the improvement. The projects on the list are then listed in the program in order of their benefit-cost ratio until the period's budget is exhausted.
2. Linear programming - benefit maximization. This procedure is the one advocated by the Ontario Ministry. It provides, basically, an optimum solution by ensuring that maximum benefit or effectiveness is derived from the expenditure within the budgetary constraints.
3. Linear programming - cost minimization. This program simply minimizes fiscal dollar expenditures without any considerations for benefits, both positive and negative. This process is mainly for the purpose of comparison and it provides a standard against which to measure the added cost from programming improvements in a priority sequence derived by the other techniques.

After extensive testing of the three different approaches, the study concluded that:

> . . . the linear programming (benefit maximization) procedure was the theoretically correct solution to the problem of assigning priorities to improvements and fulfilled the objectives set out initially for the methodology. . . . The preliminary testing indicated that the linear programming (benefit maximization) methodology will probably generate priority programs which, for given budgets, will yield a present worth of benefits one to five percent higher than other methods. (10)

Optimization Process - Comments and Critique

The optimization process is still in its development stage and quite some way from practical implementation. However, it does show a lot of promise and with further advances in the estimation and quantification of benefits and disbenefits, this may be the process of the future.

The major problem for the optimization process is to establish an objective function which requires the estimation and quantification of benefits and disbenefits. The numerous proposed procedures on such estimation and quantification are still wide open to debate despite the vast amount of research directed in these areas. Furthermore, most of these procedures are so complicated and time-consuming that an extensive overhaul in the data collection and planning processes will be necessary.

The optimization process also fails to identify the sufficiency or criticality of the improvements because it only measures the benefits and costs of an improvement. It must be stressed again that improvements with good economic returns and attractive benefits may not be those with the most critical needs while by the same token, projects with high degree of criticality may not be those that maximize the benefits.

On the bright side of the optimization process, it has the great capability of combining the processes of priority analysis, program formulation and project scheduling. The ability to determine the optimal timing of improvements is another significant advantage of the optimization process, as the effects of time, interest rate, inflation rate, and financial resources are all taken into consideration. The linear programming approach is very flexible in adopting constraints. In addition to the common constraints such as budgetary limitations, manpower availability and distributional constraints, the linear programming procedure can handle other constraints such as sequentially dependent improvements, mutually exclusive improvements, projects committed for other reasons and projects with time restrictions.

Computationally, the linear programming technique is extremely well-developed, flexible and has great capacity in terms of the number of alternatives that can be handled. Computer programs are readily available for electronic data processing which provide quick and relatively inexpensive executions and revisions. Once the data base is loaded initially and the problem solved once, additional information may be added as it becomes available. In addition to the solution itself, a sensitivity analysis can be carried out to examine the changes in priorities with respect to input data variation, together with a full economic analysis and interpretation of the solution results.

In summary, the linear programming optimization approach satisfies not only the basic quidelines of objectivity, comprehensiveness and consistency, but has many distinct advantages over the existing priority analysis procedures. However, until the estimation and quantification of benefits and consequences can be established in a satisfactory way, the sufficiency rating and its modifications will continue to be the acceptable approach despite its many drawbacks.

CHAPTER IV

PRIORITY ANALYSIS - A PROPOSED METHODOLOGY

After examining the two alternative processes - iteration and optimization - and the various existing priority analysis procedures, it appears that there can be three alternative approaches in developing a priority analysis procedure for the Georgia Department of Transportation:

1. Adopt the optimization process;
2. Adopt the iterative process, using an existing procedure with minor modifications; and
3. Adopt the iterative process, developing a new procedure.

The optimization approach was never seriously considered despite its many distinct advantages over the iterative process. The estimation and quantification of benefits and consequences of improvements is still in its developing stage and adoption of this process is deemed impractical at this time. However, technological advances in this area should be monitored closely with due consideration for the optimization process as satisfactory techniques for estimating and quantifying benefits and consequences are developed. The usage of economic analysis in an iterative process was also discarded for similar reasons.

The various existing priority analysis procedures, except that of Arizona, fail to take economic, social and environmental factors into consideration. These factors are rapidly becoming an important and, in some instances, dominant element in the planning process. It should, therefore, be expected that these factors be placed on an equally important role in the priority analysis. In addition to incorporating these economic, social and environmental factors into the analysis, another basic objective is to consider political and local inputs in a more comprehensive and systematic manner.

In order to incorporate these features into the priority analysis procedure, extensive modification would be necessary to adapt an existing procedure. A modification of this magnitude would be as large and without offering the benefits of rethinking the problems. The third alternative approach was adapted and a new procedure was developed.

Numerous ranking and selection techniques are available (49) with different degrees of complexity, sophistication and flexibility. A 'scoring model' approach was finally chosen for the proposed procedure. A model is simple to use, yet very flexible, and can be readily programmed for electronic data processing. The model also allows the use of both qualitative and quantitative inputs as well as conflicting criteria. With minor modifications, the model can be extended to include other modes of transportation.

Conceptual Framework of Priority Analysis Procedure

The scoring model concept is similar to the sufficiency rating approach. It can be expressed mathematically as:

$$S_j = \sum_{i=1}^{P} W_i R_{ij}$$

where S_j = Overall score or rating of project j;

W_i = Weighting factor (relative importance) of the i^{th} factor;

p = Number of evaluating factors; and

R_{ij} = Score or rating on the i^{th} factor of project j.

This expression is self-evident in the case of sufficiency rating - composite score, but may be less clear for priority arraying. However, if all W_i's are set equal to zero except that for a particular factor, k, under consideration, that is,

$$W_i \begin{cases} = 0 & \text{if } i \neq k \\ \neq 0 & \text{if } i = k \end{cases}$$

then the above expression will apply to the priority arraying approach as well.

The application of the scoring model to priority analysis can be viewed conceptually within the following framework:

1. The projects are categorized according to their functional classification and improvement types so that they may be evaluated and compared under similar sets of factors and consequences.
2. The factors and consequences that are pertinent to each category under consideration are identified.
3. The rating or score of each individual factor and consequence is derived through objective, analytical methods where possible, otherwise through subjective judgements for each project in each category.
4. The overall rating of all factors and consequences of each

project is developed through the use of relative weighting factors. The procedure is designed to collapse the variety of factor and consequence value ratings into one or two dimensions, thus assigning an 'overall score' to each project. Based on this overall score, the priorities of the projects can be established for each category.

Each of these four tasks will be discussed in full detail before the formulation of the new proposed priority analysis procedure.

Categorization of Improvements

It is evident that improvements under different functional classifications and types of work should be evaluated under different and compatible sets of criteria. For instance, the building of a new interstate highway in an urban area cannot be compared to an improvement such as the resurfacing of a rural surface street. These two improvements are plainly incompatible in terms of consequences, design standards, costs and funding sources. The first step of the priority analysis procedure is therefore to segregate the improvement projects into categories based on their functional classification and nature of improvement.

The categorization of improvements offers other significant advantages in addition to compatibility. At present, the funding sources for highway improvements are highly diversified with little uniformity as to functional class and type of improvement, as shown in Table 3. However, there is a definite trend towards more uniformity in the funding sources, both on the federal and on the state levels. Furthermore,

Table 3. Existing Funding Sources for Highway Improvements in the State of Georgia

Funding Sources
A. HIGHWAY TRUST FUNDS
1. Federal-Aid Highway Funds
a) Interstate funds
b) Primary funds
c) Urban funds
d) Secondary funds
e) Rural Primary funds
f) Rural Secondary funds
2. Appalachian Highway Funds
a) Appalachian Development Highway System funds
b) Local access road construction funds
3. Highway Beautification Funds
a) Landscaping and scenic enhancement
b) Control of outdoor advertising
c) Control of junkyards
4. Forest Highway Funds
5. Public Lands Highway Funds
6. Emergency Funds
7. Defense Access, Replacement and Manuever Funds
8. Highway Planning and Research Funds
9. Bridge Replacement Funds
B. STATE FUNDS
1. State Construction Funds
2. State Maintenance and Betterment Funds
3. State Airport Funds
C. GEORGIA HIGHWAY AUTHORITY FUNDS (BOND)

this categorization provides a basis for legislative and administrative directives in terms of resource allocation, fund appropriation, policy-making and system priorities.

Figure 4 illustrates how the functional classes and the types of improvement are interrelated to form the categories.

Functional Classification

Conceptually, functional classification is defined as "the process by which streets and highways are grouped into classes, or systems, according to the character of service they are intended to provide." (25) The Georgia Highway Functional Classification and Needs Study, 1970-1990 (31), which will be used in the priority analysis procedure, divides the 100,000 miles of highways and streets in the State of Georgia into ten functional classes:

1. Urban interstate;
2. Rural interstate;
3. Urban principal arterial routes;
4. Rural principal arterial routes;
5. Urban minor arterial routes;
6. Rural minor arterial routes;
7. Urban collector routes;
8. Rural collector routes;
9. Urban local routes; and
10. Rural local route.

Types of Improvement

The segregation of projects by types of improvement is much less well-defined than functional classification. An initial division into

FUNCTIONAL CLASSIFICATION		TYPES OF IMPROVEMENT								
		New Highway Construction	Reconstruction Major Highway Upgrading	Minor Highway Upgrading	Structures	Safety Improvement	Traffic Engr. Improvement	Beautification	Railroad Crossings	Special Studies
INTERSTATE	URBAN	01	02	03	04	05	06	07		09
	RURAL	11	12	13	14	15	16	17		19
MAJOR ARTERIAL	URBAN	21	22	23	24	25	26	27	28	29
	RURAL	31	32	33	34	35	36	37	38	39
MINOR ARTERIAL	URBAN	41	42	43	44	45	46	47	48	49
	RURAL	51	52	53	54	55	56	57	58	59
COLLECTOR	URBAN	61	62	63	64	65	66	67	68	69
	RURAL	71	72	73	74	75	76	77	78	79
LOCAL	URBAN	81	82	83	84	85	86		88	89
	RURAL	91	92	93	94	95	96		98	99

Figure 4. Categorization of Highway Improvement Projects

types of improvement was accomplished after extensive studies of the nature of work involved, the funding sources, and the distribution of projects under various improvement types. The initial list was then reviewed carefully by Department officials until a satisfactory segregation of projects by improvement types was reached. Nine types of improvements were finally adapted, as shown in Table 4.

The prime source of information on establishing the improvement types is the Project Management File (PMF), which contains the Georgia Department of Transportation's current five to seven year construction program. The PMF is an essential component of the Program Management System (PMS), which, in turn, is a vital subsystem of the Multiproject Programming and Scheduling System (MP/SS). The PMF codes the projects by type of improvement and each project is phased by planning, preliminary engineering, right-of-way acquisition, and construction, together with the estimated cost and year in which each project phase is to be accomplished. (27)

Figure 5 illustrates the current distribution of highway improvement projects by number and costs for each improvement type. The first four types of improvement: new highway construction, reconstruction and major highway upgrading, minor highway upgrading and structures comprise approximately 80 percent of the projects in numbers and over 92 percent of the total cost. However, the other four types: safety, traffic engineering, beautification, and railroad crossing improvements all have some features different from the first four types that preclude them from being incorporated into any of the first four types. For example, even

Table 4. Brief Description of the Nine Improvement Types

Types of Improvement
1. New Highway Construction. New Highway construction and related engineering work.
2. Reconstruction and Major Highway Upgrading. Reconstruction, relocation, re-alignment, addition of lane(s), and widening.
3. Minor Highway Upgrading. Resurfacing, repaving, grading, drainage, paving shoulders, and surface treatment.
4. Structures, New and Replacement. Bridge structure, culvert, sign support structure, and special structure.
5. Safety Improvement. Safety project, pedestrain overpass, guardrail, median, separator and sidewalk construction.
6. Traffic Engineering Improvement. TOPICS, intersection improvement, traffic signal, flash and overhead signing, and street lighting.
7. Beautification Project. Landscaping, and scenic right-of-way acquisition.
8. Railroad Crossing Projects. Railroad overpass, signal, and crossing markings.
9. Special Projects. Projects that cannot be classified into any of the above improvement types, such as rest area, weighting station, planning and research.

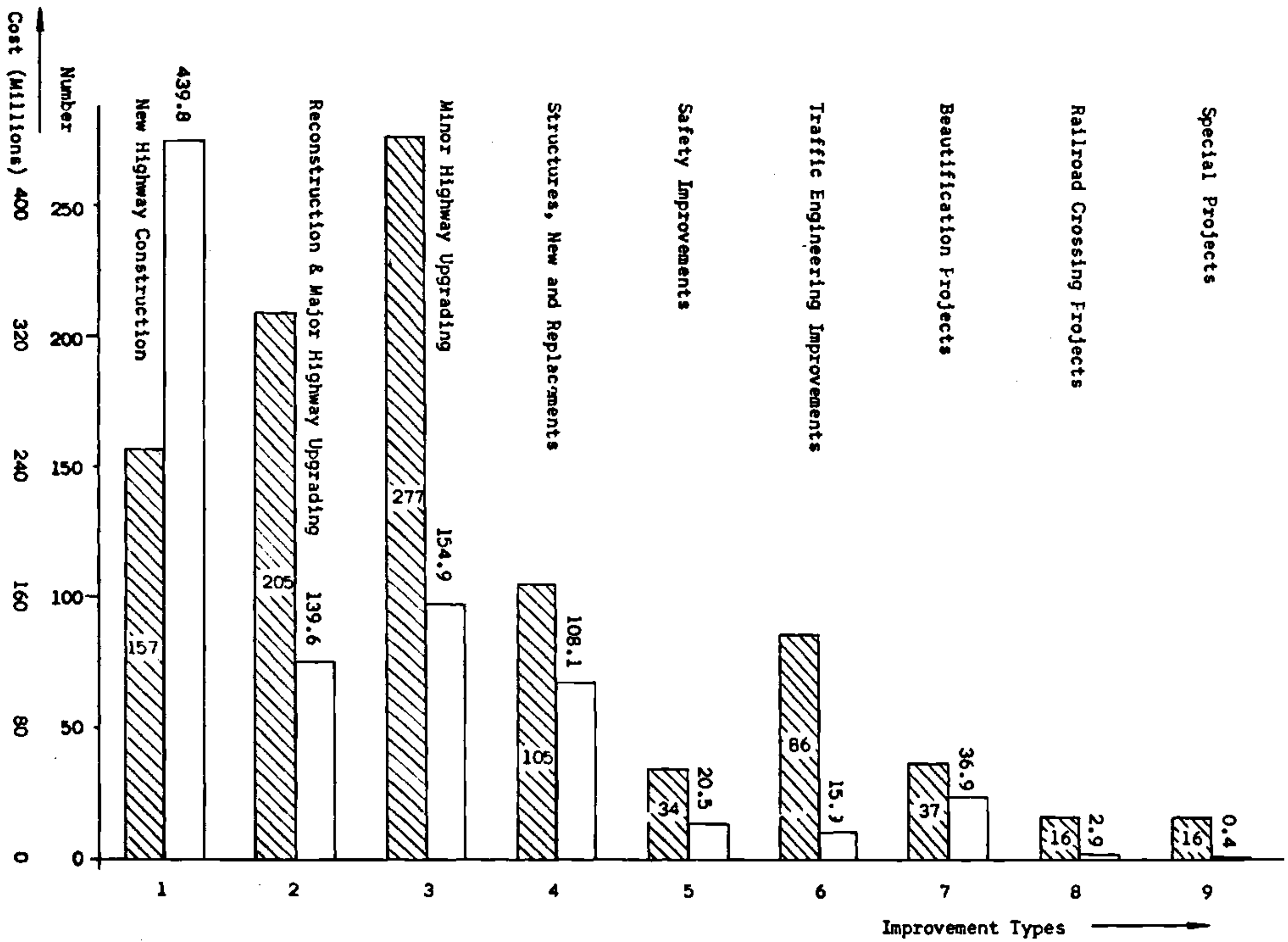


Figure 5. The Number* and Total Cost* of Current Projects by Improvement Types
*In addition, there are 54 uncategorized projects and 117 projects with no cost estimates.

though the number of beautification projects is relatively small, a beautification project cannot be compared with any other type of improvement. Moreover, it even has its own separate funding source. The last type of improvement - special projects, includes all remaining projects that cannot be classified into any of the eight above types, such as rest areas, weighing stations, etc.

Identification of Evaluating Factors

The second step in the development of the model was to identify the appropriate factors for each category. However, due to the large number of categories defined, it seemed impractical to attempt identifying appropriate factors for each category. Instead, an extensive master list of factors was established, from which each category drew its evaluating factors. To further simplify the process, all functional classes will share the same set of factors for a given type of improvement. This simplification is deemed appropriate as the selection of factors depends on the nature of the improvement type which applies to all the functional classes.

An extensive literature research was performed in order to formulate the master list of factors. There is an enormous amount of literature in this area (6-24,40-48), the prime sources being existing priority analysis procedures and other evaluation procedures, such as those used for evaluation of alternative plans and route selection. The problem thus boiled down to selecting those factors that are most significan while at the same time requiring no extensive changes in the existing data system and planning process.

Information regarding the present data system and planning process in the Georgia Department of Transportation was collected partially through review of Department publications (27-34), but mostly from interviews with Department officials. The data system and planning process were examined to the extent of data availability. To ensure maximum flexibility in the definitions of the factors chosen, no attempt is made to determine the measures and numerical values for establishing criteria. This also allows room for modifications in case of new technological advances. Furthermore, the determination of measures and criteria is part of the policy-making process and should be the responsibility of the Department officials.

After careful study and review by Department officials, a list of 26 factors was identified. These factors are considered to be the most significant factors for which data is readily available. These 26 factors are grouped under 8 broad headings:

1. Need factors;
2. Deficiency factors;
3. Continuity factors;
4. Highway-user related factor;
5. Human factor;
6. Economic consequences;
7. Social consequences; and
8. Environmental consequences.

A detailed listing of these 26 factors are shown as Table 5.

Need Factors

Whenever a project comes up for evaluation and selection in the

Table 5. Master List of Factors Identified for Evaluation

Master List of Evaluating Factors

1. Need Factors

   A. Need as identified by state, regional or local transportation plans.

   B. Need as identified by state, regional or local officials.

   C. Need as recommended by GDOT officials evaluating project.

2. Deficiency Factors

   A. Existing and projected traffic volume.

   B. Existing traffic volume/capacity ratio.

   C. Existing condition of highway facilities
      Pavement condition
      Structure condition.

   D. Accident experience (including hazard index).

   E. Existing deficiencies in roadway geometrics and alignments
      Roadway width
      Stopping and passing sight distance
      Horizontal curve
      Vertical curve
      Vertical and horizontal clearance of bridge structure.

3. Continuity Factors

   A. Continuity with existing facilities.

   B. Continuity and coordination with other improvements.

4. Highway-User Related Factor

   A. Benefit-cost ratio

Highway-user related benefits:	Travel time
	Travel cost
	Accident potential
	Travel comfort and convenience
Highway-user related costs:	Construction
	Operation and maintenance.

Table 5. Master List of Factors Identified for Evaluation (Continued)

Master List of Evaluating Factors
5. Human Factor
A. Local opinions from publications and hearings as well as requests (or compliants) from local civic groups and individuals.
6. Economic Consequences
A. Desirability with respect to state, regional and local community goals and land-use and economic development plans.
B. Consequences on land value and development.
C. Consequences on agricultural activities.
D. Consequences on commercial and industrial activities.
E. Consequences on local construction industry and employment.
F. Dislocation and/or relocation of public utilities.
7. Social Consequences
A. Disruption to community during construction.
B. Dislocation and relocation of residential and commercial units.
C. Consequences on neighborhood life and social patterns.
D. Preservation of historical, religious and institutional areas.
8. Environmental Consequences
A. Aesthetics and visual effects.
B. Air pollution, noise pollution and vibration.
C. Water pollution and effect on drainage.
D. Conservation of natural resources.

programming process, two basic and important questions are: "Do we need such an improvement?" and "How badly do we need such an improvement?". The first question is answered when the project is screened through the planning process for justification and identification of the best alternative. The three need factors that were selected are intended to answer the second question.

The degree or criticality of need for an improvement can be approached from three different angles as described below.

Need as Identified by State, Regional or Local Transportation Plans. The importance of long-range transportation plans, both on state and local levels, has been stressed before and requires no further emphasis. This factor is designed to indicate the compatibility of the particular improvement project with respect to the long-range transportation planning goals and objectives. The State of Georgia presently has no statewide long-range transportation plan, but it is expected that a statewide long-range transportation plan will be available by July, 1974. Until then, this factor will have to be evaluated either on the basis of local, regional, or urban transportation studies.

Need as Identified by State, Regional or Local Officials. This factor attempts to gauge the degree of need as indicated by the source that originates the improvement project. This may be in the form of priority lists from county commissioners, city councils, or other local, regional, or state officials. This factor is best rated by officials in the Office of Programming based on information collected from direct inputs or indirect inputs through the Department administrators.

Need as Recommended by Department Officials Evaluating the Project. The screening process for justification and selection of a best alternative will provide some indication as to the need for the improvement project under consideration. The input to this factor will usually be provided by Office of Planning officials although it can conceivably come from other sources such as from Office of Traffic Engineering and Safety on safety improvement projects. In case an improvement is originated and evaluated by the same source, this factor will be inapplicable.

All three need factors will be rated on a scale of zero to 10, with 10 especially reserved for improvements with critical need and requiring immediate action. Subjective judgements will be necessary for these factors. However, the need factor indicated by transportation plans will inject considerable objectivity into the rating.

Deficiency Factors

The five deficiency factors chosen are well-defined in existing priority analysis procedures. Criteria for degree of deficiency in these factors are established for each functional class allowing the factors to be evaluated on a systematic and objective basis. Again, the factors will be rated on a zero to 10 scale, with 10 reserved for improvements on roadways with critical deficiencies. A project with one or more ratings of 10 in the need and deficiency factors will automatically be forced to the top of the priority groups, irrespective of the overall score.

Existing and Projected Traffic Volume. The projected traffic volume at the design year is the only engineering factor presented to the State Transportation Board during the review and approval process. The importance of this factor is self-evident. Traffic volume also serves as a reasonable indicator of the demand and usage of the highway facility under consideration for improvement. The traffic volume factor may be incorporated into the evaluation by means of following two indices:

$$\text{Growth factor} = \frac{\text{Projected traffic volume}}{\text{Present traffic volume}}$$

This aspect of the traffic volume factor evaluates the criticality in the projected rate of increase in the patronage of the particular highway facility under consideration for improvement. The growth factor may be used for the evaluation of the traffic volume factor.

b. Normalizing index, which is defined as:

$$\text{Normalizing Index} = 1 + \text{Log}\left[\frac{\text{Projected traffic volume}}{\text{Estimated project cost}} \times p\right]^{q}$$

Where estimated project cost = total project cost for spot improvements, and project cost per mile for section improvements.

Log = Logarithm to the base of 10; and

p, q = Constants, which are determined when calibrating the model and may be different for different categories.

The normalizing index may be incorporated as an exponent to the individual factor ratings or weighting factors. This index may be viewed as an indicator on the importance of the number or users per unit of cost, which favors improvements on highway facilities with higher traffic volume and lower capital cost.

The logarithm of the traffic volume/cost ratio is employed to limit the range of values for the index, which otherwise will be too large or small in some cases. The constant, q, provides a means of adjusting this index to fit into the present decision-making process.

Existing Traffic Volume/Capacity Ratio. The v/c ratio reflects the level of service provided by a roadway section and is an important factor in the planning of some highway improvements. A v/c ratio of 0.70 is considered to be the critical level of service C beyond which congestion and delay will occur. The unit of measure for this factor is applicable for rural highways where the traffic volumes are usually very low. However, this factor is extremely important in urban areas where streets are often loaded to their capacities.

Existing Conditions of Highway Facilities. This factor portrays the structural adequacy of the existing highway facilities, namely, pavement, bridges, culverts and other structures. A rating system is presently in use for bridge structures in the State of Georgia. However, for pavements, culverts, and other structures, there are no established procedures other than the priority lists developed by the Office of Maintenance that are based on the recommendations of local officials and field inspectors. It is therefore highly desirable to develop a rating system developed for non-bridge facilities*. Meanwhile, the rating of this factor

*A research proposal to develop a rating system for pavement conditions is presently under consideration by the Research and Development Bureau.

will have to be based on the existing inputs.

Accident Experience. Accident data from various jurisdictions in the State are collected and computerized to form an accident data base, from which the Office of Traffic Engineering and Safety identifies the hazardous locations and makes improvement recommendations. Computer programs are available to calculate a total severity index for each location on the state highway system and to identify and rank the hazardous locations. The total severity index is a weighted combination of three safety indices based on ratios of actual to expected values of accident frequency, rate and severity. The total severity index will serve as a measure for the facilities' deficiency in terms of accident experience.

A computer program is available for railroad crossing accident experience, which lists railroad crossings with their respective number of accidents, injuries, fatalities, and property damage. The program also calculates a hazard index which is defined as the expected number of accidents in a five year period. The hazard index can serve the purpose for establishing degrees of criticality.

Existing Deficiencies in Roadway Geometrics and Alignments. A complete inventory of the existing highways and streets in Georgia has been recently completed. This road data inventory will provide the basis for identifying existing deficiencies in geometrics and alignments of roadways by comparing the actual data to the 'desirable' standards specified in design handbooks. Deficiencies in the following roadway characteristics are evaluated:

a. Horizontal curves;

b. Vertical curves;

c. Vertical and horizontal clearance of bridge structures;

d. Passing and stopping sight distances; and

e. Roadway width.

Degree of criticality for each characteristic can be determined by comparing the actual physical dimensions with the desired standards.

All these five factors may be evaluated and rated by Office of Planning officials or by offices where the input data to the factors are collected. The factors are then rated on an objective basis by evaluating the existing geometrics and alignments of the highway section in light of a set of established criteria. Individual criterion values should be established by the offices where the data is collected and then reviewed by Department administrators.

Continuity Factors

The two continuity factors will also be scored on a zero to 10 scale. The rating of these factors will be based substantially on subjective judgement.

Continuity with Existing Highway Facilities. The necessity of completing usable segments and partially completed improvements should place such projects on a high priority. A prime example of such an improvement is the completion of the Cartersville section of Interstate 75. Another aspect of continuity deserving attention is the contribution of the improvements to the continuity of the overall highway network, such as providing connecting links between principal arterial routes. This factor is preferably evaluated by Office of Planning officials based on transportation plans and local inputs.

Continuity and Coordination with Other Improvements. A good highway program should provide continuity and coordination between the improvements to facilitate the maximum effective utilization of the available resources. Certain projects can be expedited with cost reductions by simply providing such continuity and coordination. In many instances, this can also mean less inconvenience to the driving public. This factor should be evaluated by the Office of Programming officials who have an overall view of the program.

Highway-User Related Factor - Benefit-cost Ratio

The benefit-cost analysis was, for a period of time, a primary basis for evaluating highway improvements. However, its popularity has subsided considerably with the upsurge of the socioeconomic and environmental factors which examine the highway improvements from the standpoint of the whole community rather than just the driving public. The benefit-cost ratio may be considered as an indicator of the degree of importance of a proposed improvement when comparing the expected user benefits to the costs of construction and maintenance. The benefits and costs include:

Highway-user related benefits - Travel time;
Travel cost;
Accident potential; and
Travel comfort and convenience.

Highway-user related costs - Construction; and
Operation and maintenance.

If the benefit-cost ratio is greater than one, the project is considered justifiable, although in practice, improvements with higher benefit-cost ratios are given higher priorities. The benefit-cost analysis should be furnished by the Office of Planning personnel and the factor evaluated in terms of the benefit-cost ratio on a zero to 10 scale.

Human Factor

The importance of local opinions and citizen participation in the planning process has been stressed time and again. Local opinions expressed through public hearings, editorials, and direct inputs as requests or compliants from local civic groups and individuals should be collected and evaluated, probably by public relations or planning personnel. This factor will not be applicable at the present time because public reactions are not evaluated during the project selection and program formulation phases, but rather at a later stage after preliminary engineering activities. Public participation is undergoing dramatic changes and can be expected to play a more definite role in the future. This new role will provide a basis for better definition of the human factor.

Economic Consequences

The Federal-Aid Highway Act of 1970 states in part:

> . . . assure that possible adverse economic, social, and environmental effects relating to any proposed project on any federal-aid system have been fully considered in developing such project, and that the final decisions on the project are made in the best overall interest taking into consideration the need for fast, safe, and efficient transportation, public services, and the cost of eliminating or minimizing such adverse effects. . . .

This exemplifies the growing role of economic, social and environmental consequences in the planning process, and eventually in the programming process.

A total of 14 economic, social and environmental consequences have been identified. All these factors are concerned with the effects and consequences, both positive and negative, imposed on the various elements of the affected communities due to the proposed highway improvement. These consequences apply mainly to new highway constructions and, on a smaller scale, to reconstruction and major upgrading of highways. The effects due to minor highway upgrading and the remaining types of improvement are usually minimal and may not be worth the effort spent in their evaluation.

These 14 factors have been very loosely defined for the priority analysis to accomodate the continuous evolution of the factors themselves. Subjective judgements will be needed for the evaluation of these factors unless otherwise stated. Evaluation of these factors naturally falls on the Office of Planning officials performing the impact studies on proposed projects. The factors will be rated on a zero to 10 scale. Technological advances in these areas should be monitored continuously and incorporated into the priority analysis procedure as soon as possible.

Highway improvements have been considered by many as a powerful means of molding economic development patterns in affected communities. The most significant impacts are on land-use patterns and land values which are interwoven with other economic consequences. A typical example may be the construction of an urban interstate interchange, which attracts new commercial activities, multi-unit housing developments, and possibly industrial activities. This may then lead to significant changes in the land values, employment trends and other economic developments in the area.

Desirability with respect to State, Regional and Local Community Goals and Land-Use and Economic Development Plans. This factor examines the desirability of a particular improvement with respect to long-range community goals and objectives in economic development and land-use patterns. At present, information in these areas are fragmented and, in some instances, non-existent. This would render the factor not applicable. However, studies will be underway in the near future to identify statewide and local goals and objectives and to develop a statewide land-use plan. These inputs, when combined with a long-range transportation plan, will provide a sound basis for evaluating this factor.

Consequences on Land Value and Development. The effects of highway improvements on land value and development are very significant. The consequences may be positive or negative depending on the circumstances. Evaluation of this factor can be drawn from historical data on parallel facilities, coupled with subjective judgements of development experts.

Consequences on Agricultural Activities. This factor applies only to rural areas and can be either positive or negative. Improved accessibility will enhance agricultural activities while at the same time will attract other commercial and industrial activities into the area. Historical data on parallel facilities will be used to develop quantitative estimates. These estimates, coupled with subjective judgements, will serve as the basis for evaluation.

Consequences on Commercial and Industrial activities. This factor concerns only urban areas and is mutually exclusive with the preceeding factor on agricultural activities. Historical data on the impact of transportation improvements on industrial and commercial activities are readily available. Another element that needs to be considered for this factor is the land-use plans and zoning regulations which, to a great extent, affect the eventual consequences on industrial and commercial activities.

Consequences on Local Construction Industry and Employment. Highway improvements inflict both short term impacts on the local construction industry and long term effects on employment trends in the communities involved. The consequences may be positive or negative depending on the situation. Historical data on these impacts are not readily available and subjective judgements will be necessary for evaluating this factor.

Dislocation and/or Relocation of Public Utilities. The cost involved in the dislocation and relocation of public utilities is presently the fiscal responsibility of the Department of Transportation. Estimates on such costs can usually be obtained. For new highway constructions, this cost depends entirely on the location of the highway and subjective judgements may be necessary.

Social Consequences

The social consequences of highway improvements on communities have been more or less ignored in the evaluation of highway improvements until the recent upsurge of emphasis on socioeconomic and environmental consequences. Social consequences are very difficult to measure and change continuously with the passage of time and their interactions with other stimuli. Furthermore, some of the social consequences are not clearly defined and evaluation of those factors will be extremely difficult. The four social factors identified may not, therefore, encompass all the possible social consequences, but represent the most significant ones that are relatively well defined at this time.

Disruption to Community during Construction. The disruptions to normal community activities during highway improvements may take various forms, such as dust, noise, traffic congestion and accident potential. This factor evaluates the short term effects of the highway improvements on the affected communities and subjective judgements will be necessary.

<u>Dislocation and/or Relocation of Residential and Commercial Units.</u> This factor may also be considered as a short term impact in the sense that dislocations and relocations are not of a continuous nature. Nevertheless, this factor is crucial to the affected communities because of its direct impact on the lives of citizens and businesses. Strongest oppositions to the improvements typically come from the owners of affected residential and commercial units. For new highway constructions, the extent of dislocations and relocations cannot be estimated accurately until the exact locations are determined. Otherwise, this factor may be evaluated on the basis of the number of residential and commercial units that needs to be dislocated and relocated. The amount of compensations necessary may also be a factor.

<u>Consequences on Neighborhood Life and Social Patterns.</u> The evaluation of this factor is extremely difficult and has to be based solely on subjective judgements. Highway improvements definitely have effects on neighborhood life and social patterns, but the nature and extent of such impacts are hard to predict and can only be evaluated from a long-term point of view. Furthermore, even if the nature and extent of the impacts can be accessed in some cases, it will be difficult to determine whether an impact is helpful or detrimental to the best interests of the community.

<u>Preservation of Historical, Religious and Institutional Areas.</u> The value of historical, religious and institutional areas to a community is so high that any damages or ill effects to these properties are usually met with very strong oppositions. Highway improvements are no exception. For this reason, the screening process for justification and best alternative will usually eliminate those projects that encroach into historical,

religious and institutional areas. This factor may, therefore, be not applicable for most proposed improvements in the priority analysis.

Environemental Consequences

The work 'ecology' is perhaps the most powerful and most misused word in recent times. The various forms of pollution and the recent energy crisis have alarmed the public as well as the government. Strict regulations are imposed on the various sources of pollution, of which automobiles on highways are prime offenders. Environmental considerations become a vital part of planning and countless projects are being killed or postponed due to the lack of proper environmental considerations. On the other hand, countermeasures to environmental problems are poorly planned and in most cases amount to stop-gap measures rather than well planned long-term solutions.

Four environmental factors are identified for consideration in the priority analysis. These factors are presently being evaluated for new proposed highways through impact studies by the Office of Planning personnel. It may be necessary to extend the scope of these factors to other types of improvements on a more routine basis. Quantitative measures have been proposed for some of environmental factors (44), but in most cases, subjective judgements will be necessary for the evaluation of these factors.

Aesthetics and Visual Effects. All know that beauty is in the eyes of the beholder and what looks good to one may appear repulsive to others. Admittedly, this factor can be evaluated only through subjective judgements. However, this factor should take on a broader sense, involving items such as scenic vistas, design of structures, landscape architecture, rest areas and lookout points. It should also consider how well the proposed improvements blend into the existing landscape with the minimum of scarring and revegetation.

Air Pollution, Noise Pollution and Vibration. Very stringent standards and countermeasures have been established against air and noise pollution by the Environmental Protection Agency (EPA). Quantitative measures and proposed procedures have been established for the evaluation of this factor. Nevertheless, this factor is evaluated presently through impact studies and based mainly on subjective judgements, which, until the establishment of quantitative procedures, will be used in the evaluation of this factor.

Water Pollution and Effects on Drainage. This factor should be evaluated on a broad context to include all possible effects of a proposed improvement on water runoff, such as drainage, erosion and bank protection. This factor may also be used in a narrower sense to denote the effects of highway improvements on the flow and sedimentation in waterways such as bridge structures and embankments. Subjective judgements based on experience will be employed in the evaluation of this factor.

Conservation of Natural Resources. The natural resources of the state must be managed and used to the fullest extent possible for the benefit of the public. At the same time, the resources must also be preserved and protected for the use of future generations. This factor is vaguely defined to allow for maximum flexibility. It should include all effects that a proposed improvement may have on natural resources, such as construction materials and land for parks and forests.

Existing Data Availability in Georgia

A basic objective in the development of the priority analysis procedure is to produce a procedure that can be implemented in the immediate future using the existing data and requiring no major modifications in the present planning process. In selecting the 26 factors, we sought to satisfy this objective while being as comprehensive and complete as possible.

All 26 factors, especially those on socioeconomic and environmental consequences, have been defined very loosely to allow maximum flexibility in the choice of units of measure and criterion values. The determination of units of measure and criterion values is viewed as a form of policy-making which falls under the responsibility of Department officials. This task, which comprises the third step in the development of the procedure, has already been turned over to Department officials and efforts are underway to establish the units of measure and criterion values for these factors.

The data inputs necessary for the definition and evaluation of these factors are generally available, though in some instances, they are rather fragmented and not collected on a routine basis. A list of necessary and available data items and their sources of information is as shown in Table 6. This list is by no means exhaustive and is based essentially on Department publications (28,33), modified through information obtained from interviews with Department officials. Relevant and supporting data is also available from other Georgia State and Federal agencies. Table 7 shows a list of these agencies with information on available data, mainly in the area of socioeconomic and environmental factors.

After examining the current data availability situation, it may be

Table 6. Data and Usual Sources Available at Georgia Department of Transportation for Evaluating Priority Analysis Factors

Data Item/Group	Usual Source
1. Statewide long-range transportation plan and statewide plan compilation	GDOT Office of Planning, available 1974.
2. Urban transportation plans	GDOT Office of Planning, Urban area planning commissions.
3. Regional transportaiion plans	GDOT Office of Planning, Area planning and development commissions.
4. Needs study reports	GDOT Office of Planning.
5. Project study reports Route-corridor feasibility studies Cost-benefit studies Environmental impact statements/ studies Capacity studies Highway-water resources development	GDOT Office of Planning.
6. Route location reports	GDOT Office of Right-of-Way.
7. Highway functional classification	GDOT Office of Planning.
8. Traffic counts (Volumes) Continuous Seasonal Coverage Special request	Field collection.
9. Vehicle classification counts	Field collection.
10. Roadside interview O-D data	Special field survey.
11. Mail survey O-D data	Special field survey.
12. Home interview O-D data (includes telephone)	Special field survey.
13. Traffic assignments, forecasts	GDOT Office of Planning.
14. Design traffic data	GDOT Office of Planning.

Table 6. Data and Usual Sources Available at Georgia Department of Transportation for Evaluating Priority Analysis Factors (Continued)

Data Item/Group	Usual Source
15. Street capacity	Special field survey.
16. Traffic signs, signals, markings data	Local public works, GDOT Office of Traffic Engineering and Safety.
17. Traffic controls data	GDOT Office of Traffic Engineering and Safety.
18. Road inventory	GDOT Data Inventory Bureau.
19. Road inventory geometric features	GDOT Data Inventory Bureau.
20. Road inventory structure/construction features	GDOT Data Inventory Bureau.
21. Road inventory culture features	GDOT Data Inventory Bureau.
22. Road geometric characteristics	GDOT Data Inventory Bureau, Field, Local planning group.
23. Road conditions information	GDOT Data Inventory Bureau, GDOT Office of Highway maintenance, Field, Local planning group, Local public works.
24. Construction projects design features	Plan files.
25. Travel time	Special field study.
26. Travel cost data	Publications.
27. Value of person/vehicle time	Publications.
28. Accident occurrences by location	GDOT Office of Traffic Engineering and Safety, Local police files.
29. Accident rates	GDOT Office of Traffic Engineering and Safety, Local police files.

Table 6. Data and Usual Sources Available at Georgia Department of Transportation for Evaluating Priority Analysis Factors (Continued)

Data Item/Group	Usual Source
30. Accident cost data	GDOT Office of Traffic Engineering and Safety, Publications.
31. Construction cost estimates	GDOT Design Offices.
32. Maintenance cost data	GDOT Office of Highway Maintenance, Publications.
33. Construction projects costs	General files.
34. Construction projects times	General files.
35. GDOT financial information	Finance, Accounting.
36. Political inputs	State, regional and local officials.
37. Public opinions, requests	Public.
38. Private industry, business opinions, requests	Business, Industry officials.
39. Program of projects	GDOT Office of Programming.
40. Zoning maps/regulations	Local government.
41. Existing land-use	Local government, Planning agency.
42. Plans for land-use (general)	Local government, Local planning agency, Developers.
43. Economic, business information	Field survey, Local planning agency, Georgia Department of Industry and Trade, Georgia Department of Human Resources.
44. Dwelling information	Local planning agency, Special survey.
45. Local area employment	Local planning agency, Georgia Department of Human Resources.

Table 6. Data and Usual Sources Available at Georgia Department of Transportation for Evaluating Priority Analysis Factors (Continued)

Data Item/Group	Usual Source
46. Historical locations information	Publications, Local government, Civic groups, Georgia State Historical Commission.
47. Institutional environmental data Educational facilities Religious institutions Public health and safety facilities Business	Field survey, Local government, GDOT Office of Planning.
48. Residential environmental data Neighborhood characteristics Property value estimates Disruption of communities Demographic data	Field survey, Census Bureau, Local planning agency, GDOT Office of Planning
49. Ecological data Natural resources Water resources-hydrology Air, noise, water pollution	U.S.G.S., Corps of Engineers, Institutions of Higher education, Field investigation, GDOT Office of Planning, Georgia Department of Natural Resources.
50. Physiographical data Soils Drainage Geology	GDOT Materials Division, Georgia Department of Mines and Geology, Corps of Engieers, U.S. Department of Agriculture, Georgia Department of Natural Resources.
51. Population/Census tracts	Census Bureau, Local planning group.
52. Statistical reports Mileage statistics Finance statistics Traffic count statistics Vehicle weight statistics	GDOT Office of Planning.
53. State, county, urban, special maps	GDOT Office of Planning.
54. Parks maps	Federal, state, local parks agencies.

Table 6. Data and Usual Sources Available at Georgia Department of Transportation for Evaluating Priority Analysis Factors (Concluded)

Data Item/Group	Usual Source
55. Forest maps	Federal, state forest agencies.
56. City extensions, characters, government, unit boundaries	Georgia Department of State Records, Georgia General Assembly Acts, Local government officials.
57. Plats, local government ordinances	Local government.
58. Utilities locations	Utility companies, local public works, GDOT Office of Utilities.
59. Utilities characteristics	Utility companies, local public works, GDOT Office of Utilities
60. Transit information Facilities Services Routes	Transit authority/company, Public service commissions.
61. Railroad facility locations	Railroad companies.
62. Railroad facilities characteristics	Railroad companies.

Table 7. Relevent Data and Information Resources for Priority Analysis

Source Document or Material on Other	Content of Information
I. Office of Planning & Budget	
A. State Investment Plan-Annual Report	1. Statewide Program and Agency Objectives 2. Growth of Georgia Economy 3. Expenditures (State) 4. Growth Potentials for Georgia 5. Socioeconomic data of specified regions of State (Appalachian, Piedmont, Coastal) 6. Economic Development Programs and Projects (existing-planned)
B. Economic Development Plan-Report	1. Economic Comparisons (Georgia vs Nation) 2. Economic Problems in Georgia 3. Economic Development Programs and Projects (recommended)
C. Census - Complete data file, Computer Tapes	1. Social - Economic Characteristics of State (general)
D. Bureau of Economic Analysis Update - Annual Hardcopy Print-out	1. County Economic Data
E. State Planning Data Summary - Annual Report of Census Statistics mainly based on I.C. & D.	1. County Data (general) 2. Population 3. Population Trends 4. Housing 5. Family Income (distribution) 6. Employment 7. Labor Force 8. Poverty 9. Mobility 10. Educational Achievement
F. Georgia Environmental Mapping System (Gems)	1. Coordinated Inter Agency Environmental Mapping Publication

Table 7. Relevent Data and Information Resources for Priority Analysis (Continued)

Source Document or Material on Other	Content of Information
II. Department of Community Development - Industry and Trade	
A. Economic Development Profiles - Brochures, 400 total, 250 updated annually	1. Industrial Development (areas, buildings, sites for potential industry)
B. Environmental Standards Handbook	1. Summary of the Most Recent Legislation Concerning Environmental Controls
C. Survey of Georgia's Environmental Control Statues	1. Tell How the Various Departments Handle Environmental Matters as a Result of the Latest Governmental Reorganization
D. Survey of Manufacturing Wage Rates - Annual Report, 200 Classifications	1. Jobs (by area)
E. Georgia Industrial Taxes Annual Report	1. Tax Rates (county, city, State)
F. Georgia Manufacturing Directory - Annual Report, 5,600 manufacturing and processing firms	1. Industries
G. Labor Availability in Georgia - Brochure, annually updated.	1. Labor Availability Statistics (Statewide or by area)
III. Department of Community Development - Community Affairs	
A. Special Studies - Mainly from grants (701) to APDC's OPB, Office of Housing, Private Planners	1. Population 2. Economic Base 3. Land Use 4. Transportation (Local)

Table 7. Relevent Data and Information Resources for Priority Analysis (Continued)

Source Document or Material on Other	Content of Information
IV. Department of Labor	
A. Annual Report	1. Employment Statistics
B. Computer Printout - not published but available by areas, characteristics of applicants and placements	1. Labor Force Characteristics
C. Georgia Manpower Trends Report, monthly	1. Manpower trends (Statewide & SMSA's)
D. Employment and Wages Insured by the Georgia Employment Security Law-Publication, quarterly, 60-65% of Georgia workforce excluding farmers, governments, self-employed.	1. Employment (county) 2. Labor Force (county) 3. Wages (county)
E. Georgia Employment and Earnings by Industry Report, annual	1. Industrial Employment (Statewide, SMSA's) 2. Industrial Earnings (Statewide, SMSA's)
V. Department of Human Resources	
A. Report for 27 Georgia Areas (APDC's and subdivision of APDC's)	1. Family & Children Services & Facilities 2. Health Facilities & Services 3. Vocational Rehabilitation Facilities & Services
B. Environmental and Social Community Surveys	1. Social Data
C. Inspection Reports (Computer Printout)	1. Installation and Approval of Water Supplies and Individual Sewage Disposal Systems

Table 7. Relevent Data and Information Resources for Priority Analysis (Continued)

Source Document or Material on Other	Content of Information
VI. Department of Natural Resources	
A. Game and Fish Division Technical Services	1. Wildlife Needs & Values
B. Parks and Recreation Division Technical Service Section	1. Advice in Regard to Planning and Financing Recreation Programs
C. Earth and Water Division	1. Conducts Geologic Research and Investigations 2. Geologic Mapping of Georgia 3. Water Quality Data
D. Environmental Protection Division	1. Controls Water Quality Information 2. Air Quality Data 3. Solid Waste Management and Land Reclamation Data
VII. Georgia Historical Commission	
A. Archaeological Site Lists	1. Comprehensive List of Some 3,000 Archaeological Sites
VIII. Georgia Forestry	
A. 40 Different Tables	1. Tables Include: Forest Site Capabilities, Forest Cut and Growth Ration, Forest Land Ownership, Stank Stocking and Timber Volumes, Forest Soils, Forest Economics
IX. Planning Agencies (ARC, APDC's, MPC's)	
A. Area Comprehensive Plans, Area Statistics	1. Transportation Plans 2. Land-use Plans 3. Comprehensive Plans 4. Area Statistics

Table 7. Relevent Data and Information Resources for Priority Analysis (Concluded)

Source Document or Material on Other	Content of Information
X. Environmental Protection Agency	
A. Environmental Protection Technology Series, Pollution Control Research Series	1. Control of Pollution
XI. Department of Housing and Urban Development	
A. Circular 1390.2 and Other HUD Documents	1. Noise Standards 2. 4 (f) Parks 3. Relocation Housing
XII. Department of Interior	
A. Technical Assistance Reports Geological Survey Maps and Other DOI Publications	1. Replies to Specific Projects, Map Information, Water Data
XIII. U. S. Corps of Engineers	
A. Corps of Engineers Publications	1. Citizens involvement in Planning 2. Environmental Evaluation 3. Water Data

desirable to separate these 26 factors into two groups that are treated differently. Data for need and deficiency factors are readily available and are collected on a routine basis for all types of improvement. On the other hand, the remaining factors are not collected on a routine basis and data for these factors are often not available, or at best, fragmented.

For example, socioeconomic and environmental consequences are presently evaluated only for proposed new highways and would be unavailable for other types of improvement. Another example is local opinions which are evaluated mostly on proposed new highways and, to a much lesser extent, on other types of improvement. In addition, local opinions are collected after the preliminary planning has been completed and is thus not available at the time when priority analysis is first performed.

Objectivity is another aspect that favors the need and deficiency factors, since these factors reflect physical conditions that can mostly be evaluated on an objective basis using established and well-developed guidelines and standards. On the contrary, the remaining factors are new and have to be evaluated on the basis of subjective judgements which may often be biased and may change appreciably from rater to rater. Furthermore, the impacts and significance of socioeconomic and environmental consequences are still relatively unknown due to the short time that these consequences have been used to evaluate highway improvements.

A counter-argument also exists. The work reported here is based on data that at least tacitly assume that all factors will be combined into a single ranking index. Furthermore, it is not clear at this time whether these need and deficiency factors are more or less important than the remaining factors.

One can also divide the nine types of improvement into two separate groups. The first group, consisting of seven of the nine types of improvements excluding new highway constructions and beautification projects, focus mainly on the need to correct and improve an existing condition of the highway facility under consideration. For this group, the need and deficiency factors, which evaluate the relative criticality or urgency for an improvement, may merit greater emphasis. The second group consists of new highway constructions and beautification projects. For this group, the priority ranking will probably depend on all factors, without special emphasis on need and deficiency factors.

CHAPTER V

DETERMINATION OF WEIGHTING FACTORS

The fourth and last task in the development of the priority analysis procedure is to determine a set of weighting factors to collapse the variety of factor ratings into one or two dimensions, so as to establish an overall score to each project by which it can be easily compared with other projects. A set of questionnaires was thus developed with the following objectives:

1. To serve as an identification process to select the pertinent factors from the master list of 26 evaluating factors for each type of improvement. The master list of factors represents an extensive array of factors, covering all possible aspects of highway improvements. However, not all of these 26 factors are appropriate for each type of improvement and the responses would provide the basis for identifying those factors that are pertinent for each type of improvement; and

2. To provide a basis for determining an initial set of weighting factors.

The set of questionnaires, shown in Appendix A, requests the raters to evaluate the relative importance of the 26 factors for each of the nine types of improvement. The questionnaire consists of:

1. A cover letter, indicating the purpose and intended use of the questionnaire;

2. An instruction sheet, explaining how the factors should be

evaluated; and

3. Rating forms, one page for each type of improvement.

The judges were asked to rate the relative importance of each factor on a scale of zero to 10 with zero denoting no importance or inappropriateness, 10 signifying extreme importance, and values in between for the various degree of relative importance. The (0, 10) scale was chosen arbitrary because it is simple to use and most raters can perceive the importance ratings on this scale.

The questionnaires were distributed to three different groups of people who have a direct concern over the selection of highway improvement projects:

1. Georgia State Transportation Board members, each of whom represents one of the 10 congressional districts in the State, as listed in Appendix B. The Board members may be considered as the top-level decision-makers as they are responsible for the final fate of the improvement projects through the review and approval process;

2. Georgia State Department of Transportation officials. A total of 35 officials, as listed in Appendix C, were asked to fill out the questionnaire. These officials, all in responsible positions, are in one way or another connected with the origination, planning and implementation of highway improvements; and

3. Area planning and development commissions and urban area planning commissions. A total of 27 questionnaires were distributed to this group which includes 17 area planning and development commissions and 10 urban area planning commissions, as shown in Appendix D. These

planning agencies are partially responsible for the origination of local highway improvement projects and provide valuable inputs to the planning process.

Overall, 58 of the 72 questionnaires (approximately 80 percent) were returned. There was one drawback to this otherwise very encouraging results. Only two of the four top administrators of the Department replied and one of them was received too late to be included in the analysis. A breakdown of the responses by group is as shown in Table 8.

Tabulation of The Responses

The returned questionnaires were first examined carefully for completeness and usability. Factors unrated or with more than one rating on the same factor were coded as 99, denoting unusable or non-existent responses. Fortunately, only a very small percentage of the returned questionnaires had incomplete or unusable responses.

Although the raters were allowed to rate continuously on the zero to 10 scale, only four out of the 58 replies had ratings that were not of integer values. Moreover, even in those four responses, only a small number of the factors were given non-integer values. It was therefore decided that all factor ratings would be rounded to the nearest integer to simplify the coding for the analysis. Ratings with fractions of 0.5 or more were rounded to the next higher integer while fractions less than 0.5 were ignored.

The responses were coded for electronic data processing. A computer program (BMD-07D) from the Biomedical computer programs (53) was used to tabulate the responses in histogram form for each of the three

Table 8. Breakdown of Responses By Groups

Group	No. of Ques. Distributed		No. of Replies	
I		10		7 (70%)
State Transportation Board members				
II		35		27*(77%)
Department of Transportation officials				
III		27		23 (85%)
Area planning and development commissions	17		15	
Urban area planning commissions	10		8	
Total:		72		57 (79%)

*A total of 29 replies were received from this group. One was in the form of a letter while another one was returned too late to be included in the analysis.

response groups:

Group 1 - State Transportation Board members;

Group 2 - Department of Transportation officials; and

Group 3 - Area planning and development commissions and urban area planning commissions.

The means and standard deviations were computed for each group as well as the overall mean and standard deviation, excluding those ratings coded as 99. The differences between the means of the three groups were tested for statistical significance using a F-test with one-way analysis of variance. These tabulations and calculations were repeated for each of the 26 factors for each of the nine types of improvement. Sample pages of computer printout are shown in Appendix E.

The correlations and inter-relationships between the factors for each type of improvement were then evaluated employing another Biomedical computer program on factor analysis (BMD-03M). The computer programs were run on an Univac 1108 computer at the Georgia Institute of Technology computer center.

For each of the nine types of improvement, the mean importance ratings of the three judge groups for each factor were then summarized and plotted as shown in Appendix F. These graphs provide quick references to the value of the group mean ratings and graphically display the general patterns on the responses.

Analysis of Results

The analysis of the responses was developed along two directions, first on the mean importance ratings of the three groups, and secondly, on the standard deviations of the overall distribution and of each of the three groups. The mean group rating on a factor presents an average of the relative importance that the raters within a group gave to the factor. The group standard deviation serves as an indicator of the amount of dispersion among the raters within a group while the overall standard deviation applies to the combination of the three groups.

The amount of dispersion among the ratings within a group and the combination of all three groups is arbitrarily described as high, medium or low to provide some crude guidelines for the analysis. The different levels of dispersion are defined by assigning equal number of factors in each level of dispersion. In other words, the overall standard deviations of all the factors are divided into three equal groups. The top one-third is denoted as high dispersion, the middle third as medium dispersion and the bottom third as low dispersion. The criterion values for assigning levels of dispersion are thus determined as:

High dispersion, if the standard deviation $>$ 2.98;

Medium dispersion, if the standard deviation $<$ 2.98, but $>$ 2.46; and

Low dispersion, if the standard deviation $<$ 2.46.

Sample distributions of high, medium and low levels of dispersion are illustrated in Figure 6.

The differences between the means of the three judge groups were tested for statistical significance using the F-test in a one-way analysis of variances. The F ratios for statistical significance at the 5 and 10 percent levels are respectively,

```
 10.000 )              *              *******
  9.000 )              **             *******
  8.000 )              ***            ****
  7.000 )*             ******         **
  6.000 )*             ******
  5.000 )****          *****          **
  4.000 )*             **
  3.000 )              *              *
  2.000 )              *
  1.000 )
   .000 )

 MEAN         5.286       6.222         8.348
 S DEV         .951       1.847         1.873
 N            7.          27.           23.
```

Low Dispersion

```
 10.000 )*                            *
  9.000 )
  8.000 )              **             ****
  7.000 )              ***            **
  6.000 )              **
  5.000 )**            *              ******
  4.000 )              ***            ***
  3.000 )***           *****          *
  2.000 )*             ****           *
  1.000 )              ****           *
   .000 )              ***            ***

 MEAN         4.429       3.444         4.727
 S DEV        2.699       2.517         2.891
 N            7.          27.           22.
```

Medium Dispersion

```
 10.000 )              *              *
  9.000 )              **
  8.000 )*                            ******
  7.000 )*             **             *
  6.000 )**            ***
  5.000 )              ******         *****
  4.000 )*             *
  3.000 )              *              *
  2.000 )              **             **
  1.000 )*             ****           *
   .000 )*             ****           *****

 MEAN         4.571       4.038         4.455
 S DEV        3.347       3.039         3.377
 N            7.          26.           22.
```

High Dispersion

Figure 6. Sample Distributions of Low, Medium and High Dispersion

$$F_{2,54,0.05} = 3.17 \quad \text{and} \quad F_{2,54,0.10} = 2.41$$

since there are three groups and a total of 57 observations. The degree of agreement between the means of the three groups is similarly described as high, medium or low and is arbitrarily defined as:

High dispersion, if the F ratio > 3.17;

Medium dispersion, if the F ratio < 3.17, but > 2.41; and

Low dispersion, if the F ratio < 2.41.

Figure 7 shows sample examples of high, medium, and low disagreements among the three judge groups.

It is evident that the significance of the levels of disagreement for a factor is dependent on its dispersion. Displaying the relationships graphically, there are a total of nine possible combinations as shown in Figure 8.

For a factor with low or medium disagreement between the group means and low or medium dispersion, the average of the three group means is accepted as the good importance rating of the factor and is then included in the initial set of weighting factors.

A factor with high disagreement between the group means and low or medium dispersion is reviewed for the cause of such high disagreement, such as one judge group rating the factor significantly higher than the other two groups. The average of the two group means with good agreement is then accepted as the initial weighting factor. The review and evaluation of these factors is based primarily on subjective judgement after careful examination of the individual ratings.

Those factors with a high level of dispersion require further

	GROUP 1	GROUP 2	GROUP 3
11.000)			
10.000)	*	********	*********16
9.000)	*****	*********	*
8.000)		*******	****
7.000)			*
6.000)	*	**	*
5.000)			
4.000)			
3.000)			
2.000)		*	
1.000)			
MEAN	8.714	8.556	9.304
S DEV	1.254	1.717	1.185
N	7.	27.	23.

All Groups Combined

S. Dev. = 1.5
F Ratio = 1.66

Low Dispersion
Low Disagreement.

	GROUP 1	GROUP 2	GROUP 3
10.000)	*	*	**
9.000)			
8.000)	*	*	*
7.000)	*	***	
6.000)	**	**	**
5.000)		***	******
4.000)	**	**	*
3.000)		******	****
2.000)		****	**
1.000)		**	**
.000)		***	**
MEAN	6.429	3.778	4.182
S DEV	2.149	2.607	2.788
N	7.	27.	22.

All Groups Combined

S. Dev. = 2.7
F Ratio = 2.84

Medium Dispersion
Medium Disagreement.

	GROUP 1	GROUP 2	GROUP 3
10.000)	*		******
9.000)		**	***
8.000)		*	**
7.000)	*	***	
6.000)	*	**	***
5.000)	**	**	*****
4.000)		***	
3.000)		*	
2.000)	*	*****	
1.000)		*	
.000)	*	*******	***
MEAN	5.000	3.519	6.636
S DEV	3.266	3.030	3.346
N	7.	27.	22.

All Groups Combined

S. Dev. = 3.5
F Ratio = 5.81

High Dispersion
High Disagreement.

Figure 7. Examples of Low, Medium and High Disagreement

Disagreement / Dispersion	LOW	MEDIUM	HIGH*
LOW	Average of three group means accepted as final weighting factor.	Average of three group means accepted as final weighting factor.	Review for reason of high disagreement. Use average of the two 'good' group means as initial weighting factor.
MEDIUM	Average of three group means accepted as final weighting factor.	Average of three group means accepted as final weighting factor.	Review for reason of high disagreement. Use average of the two 'good' group means as initial weighting factor.
HIGH*	No conclusive weigh-ting factor. Use average of three group means as ini-tial weig ting factor.	No conclusive weigh-ting factor. Use average of three group means as ini-tial weighting factor.	No conclusive weigh-ting factor. Use average of three group means as ini-tial weighting factor.

* Factors with either high dispersion or high disagreement or both should be further investigated to obtain the final weighting factors.

Figure 8. Relationships Between Levels of Dispersion and Disagreement

investigation because with high dispersion, no significance may be attached to the levels of disagreement nor any conclusive weighting factors may be arrived. The causes for high dispersion may be poor definition of the factor, lack of knowledge about the factor on the part of the raters, indecisiveness as to the importance of the factor, or uncertainty with respect to the pertinency or inappropriateness of the factor for that type of improvement. Further investigation into these factors with high dispersion will be necessary before they can be properly introduced into the ranking procedure. However, initial weighting factors are assigned to these factors based on the average of the three group means just to provide a starting point for further refinement in arriving at the final set of weighting factors.

One of the objectives of this analysis of the responses is to identify the pertinent factors from the master list of 26 factors. A factor with high importance rating is clearly pertinent while an inappropriate factor should have an importance rating of 0.0. However, it is observed that some raters tend to use only the high side of the rating scale and shy away from using zeros. The lowest mean importance rating is in the order of 2.0. A set of crude guidelines was thus necessary to determine when a factor may be inappropriate and should be assigned a weighting factor of zero:

1. If two out of the three group means are less than 3.5;

2. If two out the three groups have one-quarter or more of the respondents rating the factor zero, or one-third or more rating it less than 2.0; or

3. If two of the three group means are less than 4.5 and with high dispersion.

The first two guidelines assert that if a factor has low mean importance ratings or a significant percentage of raters rating it inappropriate (less than the lowest mean rating of 2.0), then the factor can be considered as inappropriate. The third guideline is based on the conviction that a factor with relatively low importance rating and high dispersion may be the result of poor definition and uncertainty as to its pertinency and thus should be excluded from the list of evaluating factors.

Figure 9 shows some examples of deleted factors where at least one of the above guidelines is violated. Factors violating these guidelines were listed for each type of improvement and then reviewed for their inclusion or deletion. The decision on whether a factor should be included or deleted is based on subjective judgements after considering other aspects such as data availability, cost for obtaining the data and the pertinency of a factor for that type of improvement. An effort was made to include only those factors that are pertinent for a particular type of improvement.

For each of the nine types of improvement, the correlation matrix and the rotated factor matrix were then examined for any significant inter-relations among the factors. A correlation coefficient for a factor loading of greater than 0.60 is considered to be significant. The factor loading for each type of improvement are shown in Appendix G.

<u>General Observations on the Responses</u>

A visual examination of the graphical display of the group means,

```
              GROUP  1    GROUP  2    GROUP  3
           ..........+..........+..........+
  10.000 )                      *
   9.000 )           **
   8.000 )*          *          *
   7.000 )*                     **
   6.000 )           ***
   5.000 )*          **         **
   4.000 )*          *****      *
   3.000 )**         **         ****
   2.000 )           ****       ****
   1.000 )           ****       ****
    .000 )*          ***        ***

MEAN        4.286       3.538      3.182
S DEV       2.690       2.657      2.771
 N          7.          26.        22.
```

All Groups Combined

Mean = 3.7
S. Dev. = 2.7
F Ratio = 0.45

```
              GROUP  1    GROUP  2    GROUP  3
           ..........+..........+..........+
  10.000 )                      *
   9.000 )           **         *
   8.000 )           **         **
   7.000 )           **         **
   6.000 )                      *
   5.000 )           ***        *
   4.000 )**         **         **
   3.000 )*          **         **
   2.000 )*          ****       ******
   1.000 )**         ****       ***
    .000 )*          ******     *

MEAN        2.143       3.296      4.045
S DEV       1.574       3.036      2.968
 N          7.          27.        22.
```

All Groups Combined

Mean = 3.1
S. Dev. = 2.9
F Ratio = 1.23

```
              GROUP  1    GROUP  2    GROUP  3
           ..........+..........+..........+
  10.000 )
   9.000 )
   8.000 )                      *
   7.000 )           *
   6.000 )                      *
   5.000 )           **         ***
   4.000 )*          *          **
   3.000 )*          ***        **
   2.000 )           ****       **
   1.000 )**         *****      **
    .000 )***        ********** *********

MEAN        1.286       1.654      2.227
S DEV       1.604       1.917      2.448
 N          7.          26.        22.
```

All Groups Combined

Mean = 1.7
S. Dev. = 2.1
F Ratio = 0.71

Figure 9. Examples of Factors Considered for Deletion

as shown in Appendix F, reveals some inherent differences in the importance ratings among the three judge groups. The raters in Group 3 - area planning and development commissions and urban area planning commissions - consistently assign higher importance ratings to the economic, social and environmental factors than the Department officials in Group 2, while those of the Board members - Group 1 - fluctuate in between.

The raters from the planning commissions also consistently attach higher relative importance to the two factors associated with plans than the other two groups. These two factors are the first need factor - need as identified by state, regional or local transportation plans - and the first economic factor - desirability with respect to state, regional and local community goals and long-range, land-use and economic development plans. On the other hand, responses from Board members and Department officials indicate a higher significance placed on the third need factor - need as recommended by Department officials evaluating the project - than the raters of the planning commissions. These inherent differences between the groups often lead to the high disagreements between the group means.

This conflict in the relative importance of the factors does reflect the current trend of emphasis by the various groups. The Department officials are more concerned with engineering factors and technical details of the projects and are comparatively slower in adapting to the recent upsurge of socioeconomic and environmental factors into the planning and operation processes. On the contrary, planners are less familiar with the technical details and are more interested in the benefits and adverse consequences of the improvements. The skepticism of regional and local planners in accepting the evaluation by Department officials on improvement projects is also evidenced in their consistent downgrading of the factor - need as recommended by Department officials evaluating the project.

More in-depth examination of the individual responses on the above-mentioned factors reveals that some raters from the planning commissions assign high ratings to the economic, social and environmental consequences and to the two factors associated with plans irrespective of the type of improvement or the applicability of the factors. Furthermore, there is generally more dispersion within the group from the planning commissions than the other two groups, indicating a wide spread in the attitudes of the planners.

The Department officials, on the other hand, have fairly high degree of consensus between their importance ratings on need, deficiency and continuity factors. However, on socioeconomic and environmental factors, significant discrepencies exist. This pattern in the ratings can probably be attributed to the fact that the Department officials are more familiar with the engineering factors and vary considerably in their attitudes towards socioeconomic and environmental factors. Little significance can be attached to the dispersions among the Board members due to the small number of responses in that group.

Overall, the socioeconomic and environmental factors have relatively higher dispersion than the other factors. The main reason for such significant disagreement among the raters is that all these consequences, unlike the need and deficiency factors, are very loosely defined and there are no standards to compare them against. The importance of such factors is therefore a matter of personal attitude which depends solely on the interpretation and knowledge of the raters in these areas. The impacts and significance of these consequences are relatively unknown due to the short time since these consequences are introduced into the evaluations of highway improvements.

The inter-relationships within and between the ratings of economic, social and environmental factors follow expected patterns. significant correlations are observed consistently within the environmental factors and usually includes the fourth social factor - preservation of historical, religious and institutional areas - which may actually be considered as an environmental factor. To a lesser extent, significant correlations exist within the economic and social factors and also between the economic, social and environmental factors. The two factors on transportation, land-use and economic development plans are mostly very highly correlated as anticipated. Dependency between the deficiency factors is less frequent and more erratic, varying widely on different types of improvement. This dependency among the factors is impossible to eliminate because they evaluate the different aspects of highway improvements and are naturally inter-related with each other.

Factor analysis is based on the conviction that the 26 factors are related and they are determined, at least in part, by a relatively small number of derived common-factors. The set of common-factors may be viewed as a reference frame with unit orthogonal axes in the sample space. These common-factors are new entities which are orthogonal to each other and therefore each represents an independent piece of information. The correlations between the factors and the common-factors are then the projections of the factors onto the orthogonal axes and are called factor loadings. Detailed description of the entire algorithm is too complicated to present in this report and reference should be made to books on factor analysis for further explanation (54,55).

The common-factors identified by factor analysis for each type of improvement provide insights into the attitudes of the raters when evaluating the relative importance of the factors. The findings from the factor analysis generally reinforce the relative importance of the factors as expressed by their mean ratings and standard deviations and is a useful tool in identifying the pertinent factors for each type of improvement. Less than half of the variances (37-46 percent) are explained by the common-factors. This low percentage can be attributed to the small number of respondents compared to the number of factors (57 to 26) and also to the large dispersions between the individual raters and among the groups.

Ten common-factors are allowed for each type of improvement although the increase in variance accounted for becomes insignificant after the third or fourth common-factor. The order of the common-factors portraits the relative amount of variance explained by each common-factor. The first common-factor accounts for the largest percentage of the variance, the second common-factor the second largest, and so on. For improvement types other than new highway constructions, and reconstruction and major highway upgradings, the factors with low importance ratings and often determined as inappropriate are identified as the first or among the first three or four common-factors. This is due to the fact that these factors comprise the lower end of the ratings and thus account for a significant portion of the variance.

Since discussions on each of the nine types of improvement are very similar, so only the 'new highway constructions' type improvement will be described in detail while the others are only discussed briefly.

New Highway Construction

There is, in general, a very high level of agreement among the raters on the relative importance of all factors. There are no factors with high dispersion, only six factors with medium dispersion and twenty factors with low dispersion. (see Appendix F-1) Socioeconomic and environmental factors have, on the whole, higher dispersions than the remaining factors.

The respondents from the planning commissions follow the pattern of having higher dispersion and attaching more importance to those factors associated with transportation plans, land-use and economic development plans, and socioeconomic and environmental consequences. This trend of higher ratings by the regional and local planners accounts for all four of the factors with medium to high disagreements between the group means. The factor on need as evaluated by Department officials is also observed to have low ratings by the Group 3 raters, though not significant enough to cause a high level of disagreement between the groups.

Seven of the Department officials gave zero or inappropriate ratings to all deficiency factors, except for the traffic volume factor. The rest of the Department officials scored high ratings to all deficiency factors. Further investigation and interviews with those seven officials revealed that new highway construction may not always be connected with the deficiencies of the existing highway network, as in the case of the Appalachian highways which are built mainly for economic reasons. This is certainly a valid point and these deficiency factors should be rated as not applicable in those cases. The proposed procedure has provisions for such inapplicability and will be discussed in Chapter VI. The seven zero ratings were then excluded for the four deficiency factors under question in the calculations of the means and standard deviations, since the ratings reflect only a special case in which these factors are inappropriate, but do not represent the relative importance of these factors when they are pertinent.

High correlation is noted between the importance ratings of the transportation plan and land-use and economic development plan factors. This high correlation is expected because proposed new highway constructions should be an integral part of transportation, land-use and economic development plans. Significant correlations are also observed for the environmental factors.

The seven common-factors identified present an overview of the various facets of considerations taken in the evaluation of a proposed new highway. The social and environmental consequences emerge as the most important set of evaluation factors followed by the deficiency factors which form the first two common-factors. Need as identified by state, regional and local officials and the economic consequences constitute the third common-factor. This finding should not be surprising as the economic consequences are some of the prime concerns for the state, regional and local officials involved.

Transportation, land-use and economic development plans, which are the backbones of well-planned developments, form the fourth common-factor. Considerations in route continuity and disruption to the community during construction are also of concern and show up in the next common-factor. The projected traffic volume and benefit-cost analysis are closely related to the evaluated need by Department officials as these are two of the important considerations in the evaluation process by highway officials on proposed new highway projects. Local opinions by itself comprises the seventh common-factor indicating the importance of citizens participation in the planning process. The factor loadings of these factors on the seven common-factors are given in Appendix G-1.

Reconstruction and Major Highway Upgrading

The level of agreement for this type of improvement, though not as significant as that for new highway constructions, is still very high. None of the 26 factors have high dispersion while 15 have low dispersions, as identified in Appendix F-2. The eleven factors with medium dispersions are mostly socioeconomic and environmental factors which in general have higher dispersions than the remaining factors.

Seven factors with medium or high disagreements among the group means are identified. (see Appendix F-2) The raters from the planning commissions again score significantly higher than the other two groups on the two factors associated with transportation, land-use and economic development plans. The Board members, meanwhile, place less importance on the deficiency factor on accident experience which gives rise to medium disagreement with the other two groups. The high ratings by regional and local planners account for the remaining four questionable factors: (i) local construction industry and employment; (ii) water pollution and drainage; (iii) preservation of historical, religious and institutional areas; and (iv) conservation of natural resources.

High correlation coefficients are observed between the traffic volume factor and the volume/capacity ratio and between the existing deficiencies on conditions and alignments of the highway facilities. Environmental factors are again significantly correlated as are disruption to the community during construction and relocation of residential and commercial units.

Social and environmental consequences and existing deficiencies on the conditions and alignments of highway facilities are the most significant factors for the evaluation of this improvement type and are identified in the first two common-factors. The traffic volume factor, volume/capacity ratio and evaluated need by Department officials are also important factors, followed by consequences on commercial and industrial activities and local opinions. (see Appendix G-2)

<u>Minor Highway Upgrading</u>

Considerable discrepencies are observed both within and between the three judge groups. Half of the factors have high dispersion and eight factors have high disagreement among the group means, as shown in Appendix F-3. Most of these significant dispersions and disagreements are in the socioeconomic and environmental consequences. A probable explanation is that these consequences are of doubtful significance for minor highway upgrading improvements and this uncertainty is revealed in their ratings. In addition, the Department officials rated these socioeconomic and environmental consequences consistently lower than the raters from the planning commissions.

This raises the possibility that some of the socioeconomic and environmental factors are inappropriate and need not be included in the priority analysis. Reviews on the group means, distributions, data availability and cost, and applicability of these factors suggest that the following factors are not pertinent and should be deleted from the list of evaluating factors:

1. Consequences on agricultural activities;
2. Consequences on local construction industry and employment;
3. Dislocation and/or relocation of public utilities;
4. Dislocation and/or relocation of residential and commercial units;
5. Consequences on neighborhood life and social patterns;
6. Preservation of historical, religious, and institutional areas; and
7. Air pollution, noise pollution and vibration.

High dispersions are found on the two factors relating to transportation, land-use and economic development plans. This reflects the uncertainty as to whether minor highway upgrading improvements should or should not be a part of these plans. A definite discrepency on the importance of need as evaluated by Department officials is apparent as the judges from the planning commissions consistently score this factor lower than the other two groups.

High correlations are observed between social and environmental factors as well as between economic factors. The factors on transportation, land-use and economic development plans are also significantly correlated. The existing condition of highway facilities is identified as the most important single factor in the factor analysis. Socioeconomic and environmental consequences appear in three of the first four common-factors as these factors comprise the low end of the ratings and account for a significant portion of the variance. The need factors and the factor on land-use and economic development plans round out the remaining three common-factors. The factor loadings are shown in Appendix G-3.

Structures, New and Replacements

The importance ratings of the factors for this improvement type are very similar to those on minor highway upgrading improvements. Nine factors have high dispersion while high disagreement between group means is observed on eight factors, as shown in Appendix F-4. The raters from the planning commissions again score the socioeconomic and environmental consequences higher than the Department officials and the differences are very pronounced in this improvement type.

The condition of the existing facility is the highest rated factor, followed closely by the factors on accident experience and evaluated need by Department officials. These three factors are also the only ones with low dispersion among the raters. The significantly lower rating by the planners on the evaluated need factor accounts for the high disagreement among the group means.

Eight factors from the socioeconomic and environmenatl consequences are considered inappropriate and are deleted from the list of evaluating factors:

1. Consequences on land value and development;
2. Consequences on agricultural activities;
3. Consequences on construction industry and employment;
4. Dislocation and/or relocation of public utilities;
5. Dislocation and/or relocation of residential and commercial units;
6. Consequences on neighborhood life and social patterns;
7. Preservation of historical, religious and institutional areas; and
8. Air pollution, noise pollution and vibration.

Safety Improvements

Except for the high dispersions on eight of the factors, the raters leave little doubt as to the relative importance of the factors. Need and deficiency factors are rated very high in contrast to the low ratings on economic, social and environmental consequences, as illustrated in Appendix F-5. Furthermore, the group means agree exceptionally well and no factor have high disagreement between the group means.

The distinct pattern in the importance ratings suggests that most of the socioeconomic and environmental factors are inappropriate and can be considered for deletion. Thirteen of the 26 factors are included for evaluation and the following factors are deleted:

a. Benefit-cost ratio;

b. Economic consequences excluding that on land-use and economic development plans;

c. Social consequences; and

d. Environmental consequences, excluding that on aesthetics and visual effects.

The importance ratings on the socioeconomic and environmental factors are all correlated. The factor analysis reveals that the emphasis on the evaluation of safety projects is, as expected, on the need factor as identified by state, regional and local officials and on the deficiency factors in accident experience, alignments and conditions of existing highway facilities. (see Appendix G-6)

Traffic Engineering Improvements

The pattern of high importance ratings on need and deficiency factors and low scores on socioeconomic and environmental consequences observed on safety improvements is repeated in this type of improvement. Seven of the nine factors with high dispersion are on social and environmental consequences. Only two factors have high disagreement between the group means. The differences in ratings on socioeconomic and environmental factors by judges from the planning commissions and Department officials are still present, but to a much lesser extent, as shown in Appendix F-6.

Fourteen of the 26 factors are used for the evaluation of this improvement type and the deleted factors are very similar to those on safety improvement projects, including:

a. All economic factors, except the factor on consequences on commercial and industrial activities;

b. All social consequences; and

c. All environmental consequences, excluding that on aesthetics and visual effects.

The common-factors identified for traffic engineering improvements are different from those of safety improvements, indicating a change in the relative importance of the factors. The factors on traffic volume and volume/capacity ratio now play a much more important role for this type of improvement. (see Appendix G-6)

<u>Beautification Projects</u>

The nature of beautification projects is so different from the other types of improvement that the respondents are not positive as to what factors need to be evaluated and what should be their relative importance. The raters' uncertainty is reflected by the high dispersion of their ratings except on economic factors which all raters agree to have little importance. The limited experience since the creation of beautification projects by the 1970 Federal-aid Highway Act may also be partially responsible for this presence of high dispersion.

Appendix F-7 shows the general pattern of importance ratings on the factors. Aesthetics and visual effects is scored as the most important factor while the remaining environmental consequences and need factors are also rated relatively high. Deficiency factors and economic consequences are all rated very low though significant disagreements are present among the raters on the deficiency factors. The factors on benefit-cost ratio, and land-use and economic development plans have high disagreement between the group means, but little significance can be attached to them because of the high dispersions.

The factors included in the evaluation for this type of improvement are quite different from the others, consisting of:

a. All need factors;

b. Existing and projected traffic volume;

c. Continuity and coordination with other improvements;

d. local opinions;

e. Desirability with respect to community goals and land-use and economic development plans; and

f. All environmental consequences and the fourth social factor on the preservation of historical, religious and institutional areas.

Railroad Crossing Projects

The nature of this improvement type is also different from the others due to its interaction with another mode of transportation - railroads. Evaluation is based mainly on the need and deficiency factors which have relatively good agreements between and within the three judge groups. Slightly less importance is placed on the continuity factors and benefit-cost ratio. The socioeconomic and environmental factors are not only rated low in relative importance, but also have very high dispersion among the raters, as shown in Appendix F-8. There are also no factors with high disagreement between the groups though twelve of the factors have high dispersions that render these weighting factors inconclusive.

Only two factors from the socioeconomic and environmental consequences are considered pertinent: (i) desirability with respect to community goals and land-use and economic development plans, and (ii) aesthetics and visual effects. The remaining factors on need, deficiency, continuity, benefit-cost ratio and local opinions are all included in the list of evaluating factors.

As expected, high correlations are observed between the economic, social and environmental factors. The common-factors identified further support the importance or insignificance of the factors as described above.

Special Projects

This type of improvement is included so that any project that does not fit into the other types of improvement may be grouped under this heading of special projects. Nevertheless, a lot of inquiries were raised by the raters and several of the Department officials indicate that representative importance ratings are not feasible because of the widely varying nature of the projects that may be grouped under this heading. It is therefore decided that projects in this type of improvement will be ranked purely on a subjective basis. Fortunately, the number and cost of projects under this heading is so small compared to the total that little difficulty is expected in ranking these projects subjectively.

Determination of Weighting Factors

The weighting factors determined for new highway construction, and reconstruction and major highway upgrading improvements are mostly acceptable and reliable, requiring little refinement before they can be used in the ranking procedure. A significant percentage of the factors (30%) on the remaining types of improvement have either high dispersion or high disagreement with low or medium dispersion. Weighting factors determined from the responses on the questionnaire are inconclusive and thus require further investigation before they can be introduced into the ranking procedure. However, initial weighting factors are set for these factors to provide for a starting point for future refinements.

A second set of questionnaires is not likely to reduce the conflicts on these factors. Some reviewers are likely to ignore a second set of questionnaires because of the time required to fill them out. Others may question the appropriateness of the questionnaire approach if a new rating is requested. It seems, therefore, that the best approach is to have the weighting factors in question reviewed and determined by top Department administrators and then tested and refined during the testing and calibration process.

The average of the three group means is accepted as the good importance rating and used as the weighting factor for a factor with low or medium disagreement between the group means and low or medium dispersion. The average of the two group means with reasonable agreement is used as the weighting factor for a factor with high disagreement between the group means and low or medium dispersion. For factors with high level of dispersion, no conclusive weighting factors may be determined. However, initial weighting factors are assigned to these factors based on the average of the three group means just to provide a starting point for future refinements.

Table 9 lists the initial set of weighting factors for the eight types of improvement. Questionable weighting factors are marked with an asterisk (*) denoting that further investigation is necessary for these factors. Factors that are deleted from the list will have zero weighting factors and are noted as not applicable (NA).

Table 9. Initial Set of Weighting Factors

Factor	Types of Improvement 1	2	3	4	5	6	7	8
1. Need as identified by state, regional or local transportation plans	8.8	8.4	6.1*	5.4*	5.7*	7.2	5.1*	7.2*
2. Need as identified by state, regional or local officials	7.2	7.2	7.0	7.1	7.1	8.1	7.0	7.8
3. Need as recommended by Department officials evaluating the project	8.1	7.8	8.6*	9.0*	8.2	8.6*	7.0*	8.2
4. Existing and projected traffic volume	8.1	8.1	6.7	6.6*	7.5	7.8	5.3*	8.3
5. Existing traffic volume/capacity ratio	8.2	8.3	6.5	7.9*	7.3	8.4	NA	6.6*
6. Existing condition of highway facilities	7.1	7.5	8.7	8.7	8.3	8.1	NA	7.5
7. Accident experience	7.5*	8.3	7.9	8.7	9.6	9.3	NA	9.7
8. Existing deficiencies in roadway alignments	6.9	7.8	5.7*	7.3	8.0	8.2	NA	8.3
9. Continuity with existing facilities	7.6	6.9	4.7*	5.8	5.2*	6.8	NA	6.1*
10. Continuity and coordination with other improvements	7.9	7.7	6.0	6.4	5.8	6.8	4.8*	6.4
11. Benefit-cost ratio	6.5	6.2	4.4*	4.2*	NA	4.3*	NA	4.6*
12. Local opinions	6.3	5.9	5.1	4.5	5.9	5.7	6.6*	6.8

Table 9. Initial Set of Weighting Factors (Continued)

Factor	Type of Improvement							
	1	2	3	4	5	6	7	8
13. Community goals and land-use and economic development plans	8.9	7.6*	4.9*	6.2*	4.5*	NA	6.3*	5.7*
14. Consequences on land value and development	6.1	5.7	4.2	NA	NA	NA	NA	NA
15. Consequences on agricultural activities	5.3	4.3	NA	NA	NA	NA	NA	NA
16. Consequences on commercial and industrial activities	6.3	5.8	4.4	4.8	NA	4.2	NA	NA
17. Consequences on construction industry & employment	4.2	3.8	NA	NA	NA	NA	NA	NA
18. Dislocation and/or relocation of public utilities	3.6*	4.3	NA	NA	NA	NA	NA	NA
19. Disruption to community during construction	5.0	5.1	4.9*	4.8	NA	NA	NA	4.1*
20. Dislocation and/or relocation of residential and commercial units	6.6	6.2	NA	NA	NA	NA	NA	NA
21. Consequences on neighborhood life and social patterns	7.5	6.2	NA	NA	NA	NA	NA	NA
22. Preservation of historial, religious and institutional areas	6.8	6.8	NA	NA	NA	NA	7.0*	NA
23. Aesthetics and visual effects	6.8	6.0	4.7	6.2	4.8	5.7*	9.2	4.5*

Table 9. Initial Set of Weighting Factors (Concluded)

Factor	Types of Improvement							
	1	2	3	4	5	6	7	8
24. Air pollution, noise pollution and vibration	6.8	6.5	NA	NA	NA	NA	5.4*	NA
25. Water pollution and effect on drainage	7.8	6.6*	6.5*	7.0	NA	NA	6.2*	NA
26. Conservation of natural resources	7.7	6.7*	5.0*	5.8*	NA	NA	6.9*	NA

* Weighting factors marked with an asterisk (*) are questionable and require further investigation.

Types of improvement -

1. New highway construction
2. Reconstruction and major highway upgrading
3. Minor highway upgrading
4. Structures, new and replacements
5. Safety improvements
6. Traffic Engineering improvements
7. Beautification projects
8. Railroad crossing projects

CHAPTER VI

FORMULATION OF THE PROPOSED PRIORITY ANALYSIS PROCEDURE

After completing all the preparatory work described in the previous chapters, the proposed priority analysis procedure is ready to be formulated. A schematic diagram (Figure 10) shows the outline of the procedure. A step-by-step description of the procedure is presented in this chapter together with explanations and illustrated with some examples.

The procedure consists basically of four steps:

1. The improvement projects are first categorized based on their functional classification and types of improvement;

2. For each category, depending on the particular type of improvement, the set of pertinent factors with weighting factors greater than zero is identified. Each pertinent factor is then evaluated and rated on a zero to 10 scale;

3. The individual factor ratings of the pertinent factors for each project are then collapsed into one or two dimensions through the use of weighting factors. An overall ranking index (or indices) is thus determined for each project; and

4. The projects within each category are then ranked based on the overall ranking index (or indices). A priority list is eatablished for each category, but comparisions between categories are not possible at this time.

This procedure essentially satisfies the three basic guidelines

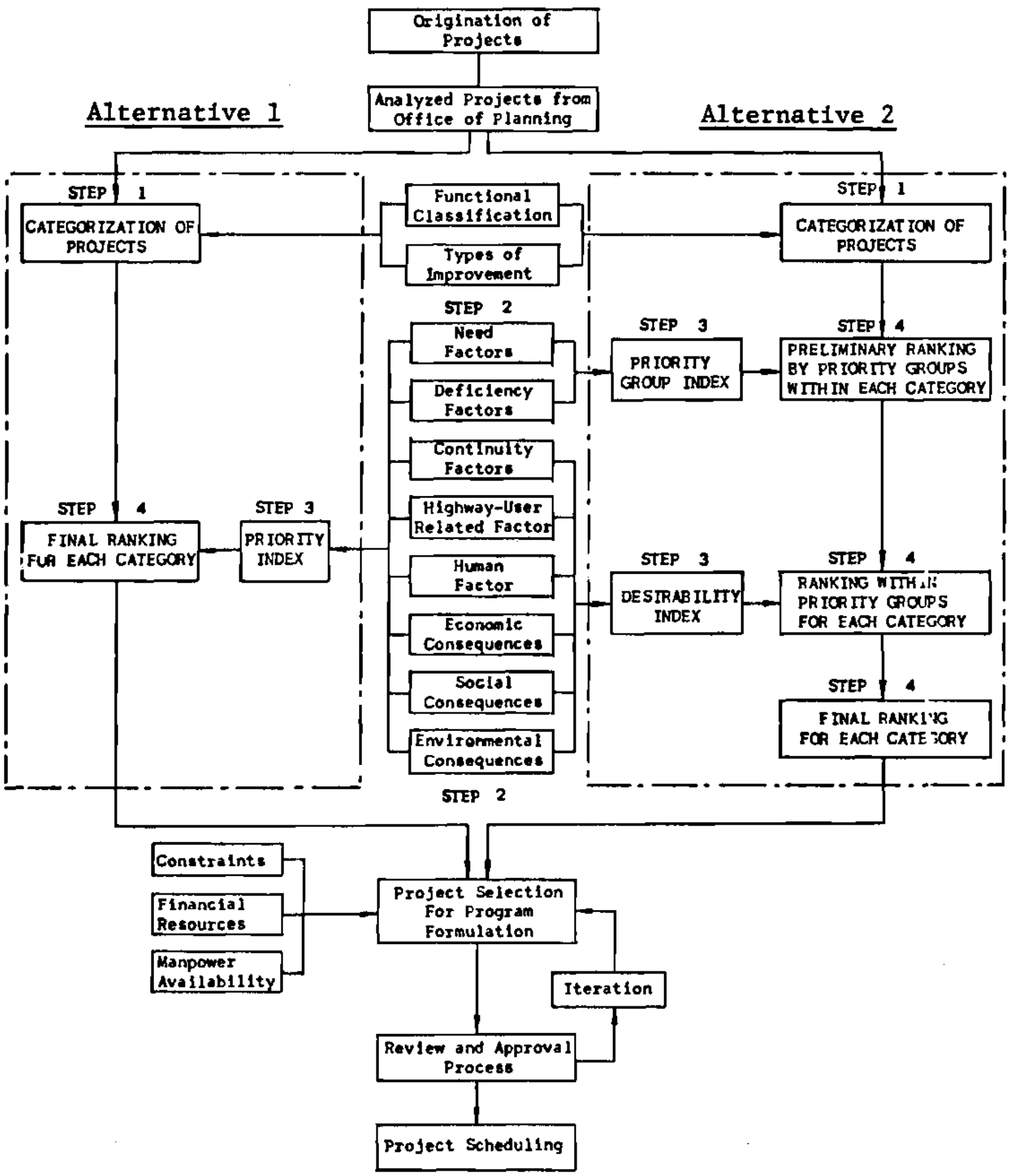


Figure 10. Schematic Diagram of the Proposed Priority Analysis Procedure

of objectivity, comprehensiveness and consistency. The inclusion of intangible factors into the procedure is perhaps the most prominent asset of the procedure, allowing both the urgency and importance of highway improvements to be evaluated simultaneously. However, some degree of objectivity and consistency has to be sacrified since intangible factors, such as socioeconomic and environmental consequences, have to be evaluated mostly on a subjective basis.

The procedure also has many other desirable features. For example, the procedure is simple to use, flexible, well adaptable to electronic data processing and has the capability of evaluating improvements with only fragmented and incomplete information. The incorporation of traffic volume and estimated cost of a project into the evaluation process is another welcomed modification to the procedure. Overall, the proposed procedure is a good procedure and an improvement over the existing procedures.

Step One

A proposed project is first categorized based on its functional classification and type of improvement. For example, a project on resurfacing an urban collector will be classified under the category (category 63 as shown in Figure 4) of minor highway upgrading for urban collector.

Step Two

For each category, depending on the particular type of improvement, the set of pertinent factors with weighting factors greater than zero is identified. For example, a project on minor highway upgrading will have the following weighting factors, assuming that these weighting factors are final. (reproduced from part of Table 9)

Factor	Weighting Factor
Need as identified by transportation plans	6.1
Need as identified by officials	7.0
Need as evaluated by Department officials	8.6
Existing and projected traffic volume	6.7
. . .	. .
Conservation of natural resources	5.0

Each pertinent factor is then evaluated using the established units of measure and criterion values and is rated on a zero to 10 scale.

Step Three

The factor ratings on the pertinent factors are then collapsed into one or two dimensions to provide the basis for ranking of the projects. There are two alternative approaches to this collapsing of factor ratings. The first alternative approach is to combine all factor ratings into one single composite score - priority index. The second approach is to divide the factors into two groups and treat them differently. The need and deficiency factors are first combined to form a priority group index. Another index - desirability index - is then calculated by combining the remaining factor ratings.

The two indices approach is based on the assertion that the 26 factors identified can be segregated into two distinct groups: (i) the need and deficiency factors which evaluate the criticality or urgency of a project; and (ii) the remaining factors on continuity, benefit-cost ratio, local opinions, and socioeconomic and environmental consequences, which identify the importance of a project. Data for the first group of need and deficiency factors are readily available and these factors may be evaluated on an objective basis. On the other hand, the second group of factors are mostly intangible, requiring subjective judgements for their evaluation which is based on data that are fragmented and often unavailable.

The form of the questionnaire suggests that all factors will be combined together to form a single index. However, the arguements above suggest that a two indices approach may be more appropriate and the responses are thus divided into two groups assuming independency. This assumption should be reviewed for its validity.

First Alternative Approach. The single factor approach is most appropriate for new highway constructions and for beautification projects. Using this approach, the factor ratings for all pertinent factors, that is, those factors with weighting factors greater than zero, are collapsed into a single composite score - the priority index. The calculation of the priority index may be expressed mathematically as:

$$P_j = \sum_{i \varepsilon M} [A_i \times (R_{ij})^{N_j}]$$

where P_j = Priority index for project j;

$i \varepsilon M$ = Factor i within the set M of pertinent factors which have weighting factors greater than zero, excluding those factors with no available information;

A_i = Normalized weighting factor for factor i;

R_{ij} = Factor rating on factor i for project j; and

N_j = Normalizing index for project j.

This expression is an extension of the basic 'scoring model' concept, which is expressed as:

$$S_j = \sum_{i=1}^{p} W_i R_{ij}$$

where S_j = Overall score or index of project j;

W_i = Weighting factor (relative importance) of the i^{th} factor;

p = Number of evaluating factors; and

R_{ij} = Score or rating on the i^{th} factor of project j.

There are, however, three major modifications to the basic scoring model concept. The first modification is that a pertinent factor with no available information for its evaluation is treated as if the factor is inappropriate, that is, as if that factor has a zero weighting factor. This modification provides more flexibility in the model to allow for evaluation of projects with only fragmented and incomplete information. The symbol $i \varepsilon M$ thus denotes those factors within the set M of factors with both the weighting factors greater than zero and information available for their evaluation.

The second modification follows as the direct result of the first one. Since some of the pertinent factors with weighting factors greater than zero may not be applicable due to lack of information, the number of evaluating factors may not be the same for all projects within the same category. This variation in number of evaluating factors poses a serious problem because the projects within the same category are no longer evaluated on the same scale or dimension. The weighting factors must therefore be converted to the same scale or dimension to accomodate this variation.

The simplest approach to this problem is to normalize the weighting factors to a (0,1) scale. This is accomplished by dividing each weighting factor within the set M of pertinent factors by the sum of all weighting factors within the set M, or expressing this mathematically

$$A_i = \frac{W_i}{\sum_{i \in M} W_i} \times s$$

where A_i = Normalized weighting factor for factor i;

W_i = Weighting factor for factor i; and

s = A constant. The multiplication of s to a (0,1) scale converts it to a (0,s) scale. The value of s may be chosen as desired.

The third major modification is the use of the normalizing index, N_j, as an exponent to the factor ratings. The normalizing index is defined as:

$$\text{Normalizing index} = 1 + \text{Log}\left[\frac{\text{Projected traffic volume}}{\text{Estimated project cost}} \times p\right]^q$$

where Log = Logarithm to the base of 10; and

p, q = Constants.

The normalizing index is designed to incorporate the cost element into the evaluation process. This index may be viewed as an indicator on the importance of the number of users per unit of cost, which favors improvements on highway facilities with higher traffic volume and lower capital cost. The constants, p and q, allow the index to be calibrated and adjusted during the testing and calibration process. The use of the logarithm function to the volume/cost ratio will moderate the effects of extremely large or small ratios.

Table 10 shows a hypothetical project on minor highway upgrading type of improvement. The factor ratings are all chosen arbitrarily to illustrate the calculation of the priority index. In this example, no information is available on the following four factors:

1. Local opinions;
2. Community goals, and land-use and economic development plans;
3. Aesthetics and visual effects; and
4. Conservation of natural resources.

These four factors are thus deleted from the list of evaluating factors as if their weighting factors are zero, and are excluded from the calculations for the priority index. The set M of pertinent factors is thus the list of factors shown in Table 11, which have both weighting factors greater than zero and available information.

The sum of the weighting factors in the set of pertinent factors, M, is equal to 92.3. (see Table 11) Suppose the value of s is set at 10, that is, on a (0,10) scale. The normalized weighting factors are obtained by dividing each individual weighting factor by the sum of 92.3 and multiplying by the value of 10. For example, consider the first need factor on transportation plans, the normalized weighting factor for this

Table 10. Data for Hypothetical Minor Highway Upgrading Project

	Factors	W_i	R_{ij}
1.	Need as identified by state, regional or local transportation plans	6.1	7.0
2.	Need as identified by state, regional or local officials	7.0	9.5
3.	Need as evaluated by Department officials	8.6	8.0
4.	Existing and projected traffic volume	6.7	4.0
5.	Existing traffic volume/capacity ratio	6.5	0.0
6.	Existing condition of highway facilities	8.7	9.0
7.	Accident experience	7.9	3.0
8.	Existing deficiencies in roadway alignments	5.7	1.0
9.	Continuity with existing facilities	4.7	5.0
10.	Continuity and coordination with other improvements	6.0	5.0
11.	Benefit-cost ratio	4.4	7.0
12.	Local Opinions	5.1	No Information
13.	Community goals and land-use and economic development plans	4.9	No Information
14.	Consequences on land value and development	4.2	1.0
16.	Consequences on commercial and industrial activities	4.4	8.0
19.	Disruption to community during construction	4.9	5.0
23.	Aesthetics and visual effects	4.7	No Information
25.	Water pollution and effect on drainage	6.5	3.0
26.	Conservation of natural resources	5.0	No Information

Note. Factors with zero weighing factors are not listed and the weighing factors are assumed to be finalized.
Traffic volume = 4,000 veh./day, Cost = $20,000.

Table 11. Calculations on Hypothetical Project - Alternative Approach 1

	Factor	W_i	R_{ij}	A_i	$(R_{ij})^{N_j}$	$A_i \times (R_{ij})^{N_j}$
		1	2	3	4	5
1.	Need as identified by transportation plans	6.1	7.0	0.66	9.39	6.19
2.	Need as identified by officials	7.0	9.5	0.76	13.33	10.13
3.	Need as evaluated by Department officials	8.6	8.0	0.93	10.94	10.17
4.	Traffic volume	6.7	4.0	0.73	4.93	3.60
5.	Volume/capacity ratio	6.5	0.0	0.70	0.00	0.00
6.	Existing condition of highway facilities	8.7	9.0	0.94	12.53	11.78
7.	Accident experience	7.9	3.0	0.86	3.54	3.04
8.	Existing deficiencies in roadway alignments	5.7	1.0	0.62	1.00	0.62
9.	Continuity with existing facilities	4.7	5.0	0.51	6.37	3.25
10.	Continuity and coordination with other improvements	6.0	5.0	0.65	6.37	4.14
11.	Benefit-cost ratio	4.4	7.0	0.48	9.38	4.50
14.	Land value and development	4.2	1.0	0.46	1.00	0.46
16.	Commercial and industrial activities	4.4	8.0	0.48	10.94	5.25
19.	Disruption during construction	4.9	5.0	0.53	6.37	3.38
25.	Water pollution and drainage	6.5	3.0	0.70	3.54	2.48
	$\sum_{i \in M} W_i =$	92.3			Priority Index =	68.99

factor is calculated by:

$$A_1 = \frac{W_1}{\sum\limits_{i \varepsilon M} W_i} \times s = \frac{6.1}{92.3} \times 10 = 0.66$$

The normalized weighting factors are listed on column 3 on Table 11.

The next step is to calculate the value of the normalizing index. Let the values p and q be set at 10 and 0.5 respectivlly. The normalizing index is then given by:

$$\text{Normalizing index} = 1 + \text{Log}\left[\frac{\text{Projected traffic volume}}{\text{Estimated project cost}} \times p\right]^q$$

$$= 1 + \text{Log}\left[\frac{4,000}{20,000} \times 10\right]^{0.5}$$

$$= 1 + \text{Log}[2.0]^{0.5} = 1 + \text{Log}[1.414]$$

$$N_j = 1.15$$

Each factor rating is then raised to the power of 1.15, the value of the normalizing index, and the resulting values are listed in column 4 on Table 11. For example, consider the factor rating on the first need factor:

$$R_{1j} = 7.0; \quad \text{and} \quad (R_{1j})^{N_j} = (7.0)^{1.15} = 9.38.$$

The value of the product $A_i \times (R_{ij})^{N_j}$ are then calculated for each of the factors, $i \varepsilon M$, and are as shown on column 5 in Table 11. The priority index for this hypothetical project is then obtained by summing the values of these $A_i \times (R_{ij})^{N_j}$ products as shown on the bottom of column 5 in Table 11, with a value of 68.99.

This process of arriving at the priority index may seem to be very cumbersome and very time-consuming. This is true if the calculations are all computed manually. However, all these calculations can be completed within a time period of milliseconds if electronic data processing is adopted.

Second Alternative Approach. This two indices approach is most appropriate for improvement projects except those on new highway constructions and beautification projects. Using this approach, two separate indices - a priority group index and a desirability index - will be used for the ranking of projects in each category. The priority group index is determined by combining the factor ratings on the need and deficiency factors only. The remaining factors on continuity, benefit-cost ratio, local opinions, and socioeconomic and environmental consequences will be collapsed into the desirability index.

The basic assertion for this two indices approach is that the 26 factors identified can be separated into two distinct groups: (i) the need and deficiency factors which evaluate the criticality or urgency of a project, and (ii) the remaining factors which identify the importance of a project. The question now is which group is more significant for highway improvements, the urgency of the project or the importance of the project.

The highways are at present the predominant mode of transportation and will likely remain so until satisfactory alternative modes are developed. In order to provide a sufficient level of mobility, service and safety to the public, the existing highway network must be maintained to an acceptable quality standard. One of the main objectives behind highway improvements is therefore to improve and maintain the conditions of the highway network to a satisfactory level. A project that is in critical need should be implemented as soon as possible and thus be given higher priority. For example, a bridge structure that is failing should be replaced or repaired as soon as possible, although it may have relatively little importance in terms of the second group of factors.

The existing data collection and planning processes also support this second approach. The data for the evaluation of the need and deficiency factors is readily available and is collected on a routine basis for all types of improvement. On the contrary, data for the second group of factors are not collected and evaluated on a routine basis and are often not available, or at best, fragmented. For example, socioeconomic and environmental consequences are presently evaluated only for proposed new highways and would be unavailable for other types of improvement.

The need and deficiency factors are also favored over the second group of factors in terms of objectivity which is one of the basic guidelines for a good priority analysis procedure. Evaluation in the need and deficiency factors is mostly performed on an objective basis with well established guidelines and standards. The factors in the second group, on the other hand, are evaluated on the basis of subjective judgements which may be biased and change appreciably from rater to rater. In addition, the impacts and significances on some of the factors in the factors in the second group are still relatively unknown due to the short time since these factors are evaluated for highway improvements. It seems therefore justifiable to use two separate indices and to place more emphasis on the need and deficiency factors in the evaluation and ranking of highway improvement projects.

The calculations involved in arriving at these two indices are very similar to those for the priority index in the first approach. The priority group index is formed by combining all factor ratings of the need and deficiency factors with the following expression:

$$PG_j = \sum_{i \varepsilon M_1} [A_i \times (R_{ij})^{N_j}]$$

where PG_j = Priority group index of project j;

$i \varepsilon M_1$ = Factor i within the set M_1 of pertinent need and deficiency factors which have weighting factors greater than zero, excluding those factors with no available information;

A_i = Normalized weighting factor for factor i;

R_{ij} = Factor rating on factor i for project j; and

N_j = Normalizing index for project j.

The priority group index indicates the relative degree of urgency for the projects. The larger the priority group index, the more urgent is the need for such a project, and vice versa.

The desirability index is calculated by collapsing the factor ratings of the remaining factors on continuity, benefit-cost ratio, local opinions, and socioeconomic and environmental consequences. The equation for the calculation of the desirability index is again very similar to that of the priority index:

$$D_j = \sum_{i\varepsilon M_2} [A_i \times (R_{ij})^{N_j}]$$

where D_j = Desirability index of project j;

$i\varepsilon M_2$ = Factor i within the set M_2 of pertinent continuity, highway-user related, human, economic, social, and environmental factors, which have non-zero weighting factors, excluding those factors with no available information;

A_i = Normalized weighting factor for factor i;

R_{ij} = Factor rating on factor i for project j; and

N_j = Normalizing index for project j.

The desirability index indicates the relative importance of the projects in terms of their benefits and consequences. The higher the desirability index, the more important is that improvement, and vice versa.

The only significant difference between the calculations of the priority index, priority group index and desirability index is in the definition of the set of pertinent factors M, M_1 and M_2, which in turn induces changes in the normalized weighting factors. Using the same set of factor ratings on the hypothetical minor highway upgrading project shown in Table 10, the priority group index and desirability index are calculated as illustrative examples and are shown in Tables 12 and 13.

For example, the sum of the weighting factors for the set M_1 of need and deficiency factors is 57.2 (see Table 12), and so the normalized weighting factor for the first need factor in transportation plans, using the same constant s of 10, is given as:

Table 12. Calculations for Priority Group Index

	Factor	W_i	R_{ij}	A_i	$(R_{ij})^{N_j}$	$A_i \times (R_{ij})^{N_j}$
		1	2	3	4	5
1.	Need as identified by transportation plans	6.1	7.0	1.07	9.38	10.04
2.	Need as identified by state, regional or local officials	7.0	9.5	1.22	13.33	16.26
3.	Need as evaluated by Department officials	8.6	8.0	1.50	10.94	16.41
4.	Traffic volume	6.7	4.0	1.17	4.93	5.77
5.	Volume/capacity ratio	6.5	0.0	1.14	0.00	0.00
6.	Existing condition on highway facilities	8.7	9.0	1.52	12.53	19.05
7.	Accident experience	7.9	3.0	1.38	3.54	4.89
8.	Existing deficiencies in roadway alignments	5.7	1.0	1.00	1.00	1.00
	$\sum_{i \in M_1} W_i =$	57.2		Priority Group Index =		73.42

Table 13. Calculations for Desirability Index

	Factor	W_i	R_{ij}	A_i	$(R_{ij})^{N_j}$	$A_i \times (R_{ij})^{N_j}$
		1	2	3	4	5
9.	Continuity with existing highway facilities	4.7	5.0	1.34	6.37	8.54
10.	Continuity and coordination with other improvements	6.0	5.0	1.71	6.37	10.89
11.	Benefit-cost ratio	4.4	7.0	1.25	9.38	11.73
14.	Land value and development	4.2	1.0	1.20	1.00	1.20
16.	Consequences on commercial and industrial activities	4.4	8.0	1.25	10.94	13.68
19.	Disruption during construction	4.9	5.0	1.40	6.37	8.92
25.	Water pollution and effect on drainage	6.5	3.0	1.85	3.54	6.55
	$\sum_{i \in M_2} W_i =$	35.1			Desirability Index	= 61.51

$$A_1 = \frac{W_1}{\sum_{i \varepsilon M_1} W_i} \times s = \frac{6.1}{57.2} \times 10 = 1.07$$

Similarly, the sum of the factors in the second group of factors is given as 35.1 (see Table 13), and the normalized weighting factor for the first continuity factor on existing facilities, using the same constant s of 10, is given by:

$$A_9 = \frac{W_9}{\sum_{i \varepsilon M_2} W_i} \times s = \frac{4.7}{35.1} \times 10 = 1.34$$

The rest of the calculations are identical to those on the priority index in the first alternative approach. The normalizing index, N_j, is unchanged at 1.15, so the value of $(R_{ij})^{N_j}$ is also unchanged. To illustrate this series of calculations once again, consider the first need factor on transportation plans:

$$A_1 = 1.07; \qquad N_j = 1.15; \qquad R_{1j} = 7.0;$$

so $$(R_{1j})^{N_j} = (7.0)^{1.15} = 9.38;$$

and $$A_1 \times (R_{1j})^{N_j} = 1.07 \times 9.38 = 10.04$$

The priority group index and desirability index are obtained by summing up all these $A_i \times (R_{ij})^{N_j}$ values for all factors within the set of pertinent factors M_1 and M_2 respectively. The priority group index and desirability index so obtained are 73.42 and 61.51 and are shown at the bottom of column 5 of Tables 12 and 13 respectively.

Step Four

The last step in the proposed procedure is to rank the projects in each category using the single priority index where it has been calculated using the first alternative approach, or the two separate indices - priority group index and desirability index - where they have been developed using the second alternative approach.

First Alternative Approach. The ranking of projects in each category using the first alternative approach is based solely on the priority indices of the projects. The project with the highest priority index is ranked first, the project with the next highest priority index is ranked second, and so on. To illustrate this process, consider the following priority indices of five hypothetical projects:

Project	Priority Index	Rank
A	70.2	3
B	68.9	4
C	95.7	2
D	100.0	1
E	42.3	5

Project D has the highest priority index of 100.0 and is therefore ranked first, followed by Project C with the second highest index of 95.7. The ranking continues until the fifth and last project E with the lowest index of 42.3.

Second Alternative Approach. The ranking of projects in a category using the second approach is much more complicated due to the use of two separate indices. The projects in each category are first arranged in descending order of their priority group indices and then divided into a number of priority groups. This division of projects into priority groups is designed to cluster projects of similar degree of urgency into the same priority group within which the projects are ranked in order of their desirability indices. The number of priority groups is arbitrarily chosen to be five and may be changed if deemed necessary.

Priority group boundaries can be established by: (i) a set of criterion values on the priority group index, or (ii) assigning roughly equal number of projects into each priority group.

Using criterion values for division into priority groups, suppose c_1, c_2, c_3 and c_4 are the boundary criterion values that establish the five priority groups. If the priority group index of a project is greater than c_1, that project will fall into the first priority group. A project with priority group index between c_1 and c_2 will be assigned to the second priority group. The third group will include projects with priority group indices between c_2 and c_3. Projects will be placed in the fourth priority group if the priority group indices are between c_3 and c_4, and finally, the fifth group if the indices are less than c_4.

Using equal grouping, each priority group will be assigned roughly equal number of projects. For example, if there are a total of 15 projects in a category, then each priority group will be assigned three projects.

In addition to high priority group index, there is another way that a project may be assigned to the first priority group. A project with one or more of the need or deficiency factors rated critical, that is, with a factor rating of 10, will immediately be placed in the first priority group. The reasoning behind this modification is that a project which has one or more critical need or deficiency factors demands immediate attention and should therefore be placed on the top of the priority list.

To illustrate this rather complex process, consider the 15 projects listed in Table 14, with hypothetical priority group indices and desirability indices. The projects B and H have one or more of the factors rated as critical, that is, with a factor rating of 10. These two projects will automatically be placed in the top priority group.

Tee remaining projects are then assigned to the priority groups either by the criterion values approach or by assigning equal number of projects in each priority group. Suppose that the criterion values approach is adopted with the following criterion values of 90, 75, 60, and 45 for c_1, c_2, c_3 and c_4 respectively. The assignment of projects into priority groups is thus determined by:

Priority Group	Criterion Values
1	$90 < PG_j$
2	$75 < PG_j < 90$
3	$60 < PG_j < 75$
4	$45 < PG_j < 60$
5	$PG_j < 45$

All projects with priority group index greater than 90 is placed into the first priority group in addition to those projects with one or more factors having a critical rating of 10. The projects C, N and O thus join the two projects B and H with critical ratings to form the first priority group. The priority group index for Project E is 76.8 and that for Project J is 87.4. Since both indices are between the values of 75 and 90, these

Table 14. Determination of Priority Groups

Project	Priority Group Index	Desirability Index	Criterion Values†		Equal Number	
			Priority Group	Rank	Priority Group	Rank
A	73.4	61.5	3	9	3	9
B	68.5*	45.7	1	2	1	1
C	92.1	15.3	1	5	2	6
D	48.6	39.6	4	12	5	15
E	76.8	77.3	2	6	3	7
F	55.3	65,4	4	11	4	11
G	57.4	88.1	4	10	4	10
H	41.5**	33.1	1	3	1	2
I	62.9	72.9	3	8	3	8
J	87.4	63 1	2	7	2	4
K	51.1	37.2	4	13	4	12
L	24.5	45.4	5	15	5	14
M	38.7	86.6	5	14	5	13
N	96.2	45.9	1	1	2	5
O	100.3	20.3	1	4	1	3

* Project B has a critical rating of 10 on the volume/capacity ratio.

** Project H has two factors with critical rating of 10, accident experience and need as identified by state, regional or local officials.

† The criterion values used are:

Priority Group	Criterion Values
1	$90 < PG_j$
2	$75 < PG_j < 90$
3	$60 < PG_j < 75$
4	$45 < PG_j < 60$
5	$PG_j < 45$

two projects are placed in the second priority group. This process is repeated for each of the five priority groups and the resulting priority groups for the projects are shown on column 4 in Table 14.

The alternative approach is to assign equal number of projects to each priority group. Since there are a total of 15 projects, each priority group will have three projects. The top priority group already has projects B and H due to their critical ratings and so only one more project may be added to this group, which is Project O with the highest rating of 100.3. The second priority group consists of the projects with the next three highest indices, which are projects N, C and J. The resulting assignment of priority groups is shown on column 6 under the heading of 'Equal Number' in Table 14.

The projects within each priority group is then ranked in order of their desirability indices. Consider priority group 1 of the criterion values approach and arranged the projects within the group in descending order of the desirability indices, as illustrated below:

Project	Desirability Index	Ranking
N	45.9	1
B	45.7	2
H	33.1	3
O	20.3	4
C	15.3	5

The projects for each category are then ranked first in order of the five priority groups and then by their desirability index within each priority group. Projects in the first priority group will be ranked higher than those in the second priority group, which in turn are higher than those in the third priority group and so on for the final ranking. It should be stressed at this point that the projects are ranked only within each of the categories and not between categories. In other words, there is a priority list of projects for each category, but comparisons between categories are not possible.

This process can best be explained by using an illustrative example. Consider the first three priority groups under the criterion values approach:

Priority Group	Project	Desirability Index	Ranking Within Group	Overall Ranking
1	N	45.9	1	1
	B	45.7	2	2
	H	33.1	3	3
	O	20.3	4	4
	C	15.3	5	5
2	E	77.3	1	6
	J	63.1	2	7
3	I	72.9	1	8
	A	61.5	2	9

The overall ranking for the criterion values approach is shown in column 5 while the overall ranking for the equal number grouping approach is shown in column 7 of Table 14. A casual examination of the final rankings reveals some significant differences between the two alternatives. For example, Project N is ranked first by the criterion values approach, but only fifth by assigning equal number of projects in each priority group. However, most of the discrepencies are very minor. At any rate, these two alternatives should be tested during the testing and calibration process to determine which one is more appropriate for the procedure.

Comparision of Alternative Approaches

Two alternative approaches are devised for the procedure. The first alternative approach uses only one single composite score - the priority index - to rank the projects within each category. Two separate indices - a priority group index and a desirability index - are employed in the second approach. The priority group index is based on the need and deficiency factors alone, while the remaining factors are combined to form the desirability index.

It is not possible to determine at this point which alternative will be more appropriate and extensive testing is necessary before any conclusions may be drawn about these two alternatives. However, it seems to the author that the first alternative is more applicable to new highway constructions and beautification projects while the second alternative is better for the other types of improvement, excluding special projects which will be evaluated and ranked subjectively.

For new highway constructions, the socioeconomic and environmental consequences are often more important than the need and deficiency factors. A similar situation exists for the beautification projects where environmental factors are rated highest, followed closely by the need factors while the deficiency factors are not even applicable. This situation favors the use of a single priority index which combines all appropriate factors.

On the other hand, the need and deficiency factors are more important in the remaining types of improvement due to their higher importance ratings, better data availability, and more objectivity in the evaluation process. This calls for the use of the second alternative with two separate indices which places more emphasis on the need and deficiency factors.

Testing and Calibration of Proposed Procedure

The validity and practicality of the proposed procedure cannot be established without an extensive and thorough testing and calibration. However, the testing and calibration of the procedure have not been undertaken as part of this research, but will be carried out by the Department to the implementation stage.

The testing of the procedure can be approached from two different view points. The first approach is to select a set of previously programmed projects with established priorities. These projects may be chosen from the current six-year program or from one of the regional or urban area transportation studies. The priorities of these projects have already been established though based mostly on subjective judgements. Nevertheless, these projects have been approved and therefore reflect the current trend of priority determination.

The second approach to testing the procedure is by selecting a set of current or hypothetical projects. A panel of judges, probably chosen from among the Board members, Department officials, representatives from regional and local planning commissions as well as other government officials and citizens, is then asked to rank the projects.

Using either approach, the same set of projects is then evaluated employing the proposed procedure. The resulting priority list, or lists, is then compared with the priorities established by one of the two approaches. The various components in the proposed procedure can then be adjusted to arrive at an acceptable and practical process. The following components of the procedure may be considered in the testing and adjustment of the procedure:

1. The set of initial weighting factors determined through the questionnaires is the prime target for refinement. There are considerable dispersions among the raters within and between the three judge groups on the relative importance of some of the evaluating factors. The initial weighting factors thus determined are crude and need some form of conflict reducing process, such as the Delphi technique, to arrive at a set of values that will be agreeable to the top Department administrators and the Transportation Board members. The initial set of weighting factors, nonetheless, provides a good starting point for the establishment of the final weighting factors.

2. The units of measure and criterion values set for each individual factor are another major area for adjustments. This is especially important since the factors are defined rather loosely to allow for flexibility in the choice of units of measure and criterion values. It is necessary to point out that poorly defined units of measure and criterion values will result in biased and even erroneous factor ratings, which in turn will affect the ranking index, or indices, for the improvement projects.

3. The normalizing index, N_j, being an exponent to the individual factor ratings, can significantly alter the outcomes of the priority index, or indices. The normalizing index is designed to incorporate the

effects of the traffic volume and project cost elements into the procedure. and the concept of such a normalizing index needs to be tested. If this index contributes to the quality of the procedure, it is then necessary to determine values for the constants p and q to best fit the procedure.

4. The two alternative approaches of a single priority index against two separate indices - priority group index and desirability index - should be evaluated and compared to determine which is the better approach. This evaluation should be carried out separately for each type of improvement since the preference of alternative approaches may change from one type of improvement to another.

5. The number of priority groups and the two alternative methods of assigning the projects into the priority groups may also offer some minor refinements to the proposed procedure.

The best and most acute test of the proposed procedure is perhaps by preparing an actual highway program for next year based on this procedure. The program will then be submitted to the review and approval process. The acceptance or rejection of the procedure hinges heavily on this actual application. A successful program will boost the confidence of the Transportation Board members, Department officials, and other state, regional and local officials and planners in the procedure while a poor showing may result in skepticism and even opposition to the future implementation of the procedure. At any rate, the final calibration of the procedure should be based on the outcome of this actual application.

Comments on the Proposed Procedure

The three basic guidelines of objectivity, comprehensiveness and consistency are essentially satisfied by the proposed procedure. The comprehensiveness of the procedure is insured by identifying the appropriate factors for each type of improvement from a master list of factors. Objectivity and consistency are preserved in the procedure through the need and deficiency factors which can be objectively evaluated based on well established guidelines and standards. This is one of the reasons for employing a two indices approach which places more emphasis on these need and deficiency factors.

The biggest asset of the proposed procedure is the inclusion of intangible factors. Socioeconomic, environmental, continuity factors as well as state and local inputs are accounted for in arriving at the priorities. These factors are often more important than the tangible factors in the evaluation of highway improvements and their importance is expected to increase with time.

However, in evaluating these intangible factors, objectivity and consistency may be more difficult to achieve. Subjective judgements, which are required for most of these factors, change and conform with the current trend of value that is molded by new emphasis and technological advances. For example, socioeconomic and environmental consequences have appeared on the scene of highway improvement evaluations only within the last decade or so, but the impact of this upsurge needs no further description. The procedure will be able to adapt to such changes by modifying the definitions, units of measure and criterion values of the factors. The weighting factors of the parameters may also be revised and updated continuously to conform with the changing emphases. However, some objectivity and consistency will have to be sacrificed in incorportating these intangible factors.

The fact that the procedure is flexible, simple to use, and well adaptable to electronic data processing should not be overlooked. The number, magnitude and complexity of present highway programs make the task of programming a monstrous undertaking. Any technical assistance in simplifying this task should be of great help to the programming process.

The procedure also has the capability of evaluating improvements with only fragmented and incomplete information. Factors that are pertinent, but have no available information, will be treated as if they are inappropriate with weighting factors of zero and will not figure in the final priority score. Then, as additional information becomes available, the projects may be re-evaluated based on the new data. The incorporation of the traffic volume and estimated cost elements into the procedure is another small, but significant addition to the process.

Some drawbacks observed in the existing procedures are also present in the proposed procedure, though to varying degrees. The obscuring of individual factor criticality by a composite score is partially offset in the two indices approach by placing all improvements with one or more critical need or deficiency factors to the top priority group irrespective of their priority group indices. No such provision is devised for the single priority index approach.

The sufficiency rating approach as used in most existing procedures rates on the deficiencies, or sufficiencies of the highway facilities, but not on the improvements themselves. On the other hand, the economic analysis approach rates on the importance of the improvement and fails to identify the degree of urgency or criticality. The proposed procedure combines both these aspects with the need and deficiency factors evaluating the criticality and the remaining factors assessing the importance and impacts of the improvements. Furthermore, factors of conflicting interest may be evaluated simultaneously by the procedure.

The procedure may also be extended to include multi-modal transportation improvements such as projects in mass transit and airport development. The basic framework of the procedure may be retained. The major area of modification is in the re-definition of the evaluating factors and probably the introduction of some new factors. New sets of weighting factors, units measure and criterion values will also be necessary for the evaluation of improvement projects in other modes of transportation.

Overall, the proposed procedure is definitely a step in the right direction in the priority analysis process. There are still a lot of work to be done before this procedure can be implemented and evaluated for its applicability. However, it may be said at this time that the procedure is a good procedure and an improvement over the existing procedures.

CHAPTER VII

SUMMARY AND CONCLUSIONS

This research is concerned with the development of a priority analysis procedure for ranking highway improvement projects. This procedure is intended for use by the Georgia State Department of Transportation and the procedure has been specifically designed for this setting.

The entire programming process was first examined to determine the inter-relationships among priority analysis and other components of the programming process. An extensive literature research was performed to review the existing priority analysis procedures employed by other states and urban areas. Existing priority analysis procedures were evaluated for their direct applicability or applicability with minor modifications. Available ranking and selection techniques were also considered for the development of a new procedure.

A set of candidate parameters that might be appropriate for the evaluation of highway improvements were identified and reviewed with respect to their data availability. A set of questionnaires was prepared and distributed to three separate groups that represent different viewpoints with respect to project selection. The responses to these questionnaires were used to identify the appropriateness of the various candidate factors as well as their relative importance in the priority analysis of the highway improvement projects. Finally, the structuring of a priority analysis procedure was formulated in light of the alternative approaches and implementational details.

The most significant findings and conclusions from this research are:

1. A 'scoring model' appears to be the best approach for a priority analysis procedure. The scoring model approach follows the general framework of an iterative process. The alternative optimization process and the economic analysis approach for an iterative process were never considered seriously because of difficulties in estimating and quantifying the benefits and adverse consequences of highway improvements. The sufficiency rating approach for an iterative process was also discarded in favor of the scoring model approach.

2. Highway improvement projects will be categorized according to their functional classification and types of improvement. The categorization provides for the necessary compatibility in the evaluation of the projects while allowing for flexibility in conforming with funding sources, distributional constraints, and legislative and administrative directives.

3. Twenty-six factors were identified for evaluation for the priority analysis. These factors are believed to be the most significant factors that might influence priority ranking. These 26 factors are grouped under eight broad headings:

i. Need factors;

ii. Deficiency factors;

iii. Continuity factors;

iv. Highway-user related factor;

v. Human factor;

vi. Economic consequences;

vii. Social consequences; and

viii. Environmental consequences.

These 26 factors are defined loosely to allow for flexibility in the choice of definitions, units of measure and criterion values that relate to the improvement types. Each factor is evaluated on a zero to ten scale.

4. Data inputs necessary for evaluating the 26 factors are basically available, although in some instances, they are rather fragmented and are not collected on a routine basis. Data for need and deficiency factors are most readily available and are collected on a routine basis for all types of improvements. Most need and deficiency factors can be evaluated on an objective basis with well established guidelines and standards. The remaining factors have to be evaluated on the basis of subjective judgements with fragmented data which are not collected on a routine basis. The good definitions of need and deficiency factors suggest that they be treated differently and perhaps with more emphasis than the remaining factors on improvement types other than new highway constructions and beautification projects.

5. The questionnaires were distributed to three different groups of people who have a direct concern over the selection of improvement projects: (i) State Transportation Board menbers, (ii) Department of Transportation officials, and (iii) regional and local planners. Approxi-

mately 80 percent of the questionnaires were returned. The following significant findings are osserved from the responses:

a. There is a high level of agreement both within and between the three judge groups for two improvement types: (i) new highway constructions, and (ii) reconstructions and major highway upgrading improvements.

b. High level of dispersion among groups are observed for the remaining improvement types, especially on socioeconomic and environmental factors.

c. The raters from regional and local planning commissions consistently assign higher importance ratings to the economic, social and environmental factors than the Department officials. Responses of the Board members fluctuated between those of the other two groups.

d. The raters from the planning commissions consistently attach higher relative importance to the two factors associated with transportation, land-use and economic development plans and lower ratings to the factor on need as evaluated by Department officials than the other two groups.

e. The Department officials have fairly high degree of consensus on their importance ratings for need, deficiency, and continuity factors. However, significant discrepencies frequently exist on the relative importance of the socioeconomic and environmental factors.

f. Significant correlations are observed between the environmental consequences and, to a lesser extent, between the economic and social factors.

g. The common-factors identified by factor analysis are very distinct and instructive as to the attitudes of the raters in evaluating the relative importance of the various factors. The common-factors also vary with the type of improvement, indicating a change in the relative importance of the evaluating factors.

h. The importance ratings on the factors provide the necessary basis for the identification of the pertinent factors for each type of improvement. All factors found to be inappropriate are assigned a weighting factor of zero.

i. An initial set of weighting factors was determined from the responses. However, 30 percent of the factors have either high dispersions or high disagreements among the judge groups that their weighting factors so determined are inconclusive and further investigation into these factors is necessary.

6. Two alternative approaches were considered to collapse the factor ratings into one or two dimensions to provide the basis for ranking of improvement projects:

i. Using the first alternative, all factor ratings are combined into one single composite score - priority index. The projects within each category are then ranked in order of their priority indices; and

ii. Using the second alternative, two separate indices - a priority group index and a desirability index - are used for the ranking of projects in a category. The priority group index is determined by combining the ratings on the need and deficiency factors. The desirability index is determined by collapsing the remaining factor ratings into a single index. The projects in each category are divided into five priority groups on the basis of their priority group indices. The projects within each priority group are then ranked in order of their desirability indices.

7. The projects are ranked only within each of the project categories. Comparisons between categories are not possible at this time.

8. The proposed procedure satisfies the basic guidelines of objectivity, comprehensiveness, and consistency. The procedure is also flexible, simple to use, and well adaptable to electronic data processing. In addition, improvements with only fragmented and incomplete information can be effectively handled by the procedure with provisions for future re-evaluation as additional information becomes available. Another desirable modification to the procedure is the incorporation of the traffic volume and project cost elements as the normalizing index.

9. Testing and calibration of the proposed procedure have not been undertaken as part of this research. However, this testing and calibration process is planned by the Department.

10. The 'special projects' type of improvements has been dropped from the procedure due to the wide variety of projects that may be grouped under this heading. Special projects will be ranked on a purely

subjective basis.

Suggested Areas for Further Research

In the course of developing the proposed procedure, several other areas of research interest have been noted. The purpose of this section is to indicate a few desirable extensions to the work which may lead to further research in the refinement and application of the procedure.

1. The testing and calibration of the proposed procedure is the first area requiring further research, since the acceptability and practicability of the procedure cannot be established without an extensive and thorough testing and calibration. This is a direct continuation of the present research work, and is needed to carry the proposed procedure to its implementation stage. A brief discussion on this topic has been presented in Chapter VI and will not be repeated here.

2. The definitions of the individual factors need to be more precise and units of measure and criterion values need to be developed. A considerable amount of research work has been done in this area, especially on the deficiency factors and more recently on the socio-economic and environmental consequences. However, there is so much more that needs to be accomplished in this area, particularly in estimating and quantifying benefits and adverse consequences of highway improvements.

3. The third area of interest is concerned with the application of the proposed procedure in the formulation of the highway program. The outputs from the priority analysis procedure are priority lists for each category. Since priority lists cannot be compared between categories

at this time, there will be problems in using these priority lists for program formulation. A linear programming formulation seems very promising in this aspect. Linear programming can handle large number of constraints, including budgetary constraints, distributional constraints and resource availability constraints. The biggest problem seems to be the definition of the objective function. The precise units of measure that are being maximized or minimized in the objective function are not clear. There has been relatively little work done in this area and more is needed to expedite the whole programming process.

APPENDIX A

QUESTIONNAIRE FORMS

Department of Transportation

State of Georgia
No. 2 Capitol Square
Atlanta, Georgia 30334

DOWNING MUSGROVE
[redacted]
COMMISSIONER
EMORY C. PARRISH
DEPUTY COMMISSIONER

THOMAS D. MORELAND
STATE HIGHWAY ENGINEER
W. M. WILLIAMS
SECRETARY-TREASURER

SUBJECT: PRIORITY ARRAY ANALYSIS

The Office of Programming is presently in the process of developing a system for ranking transportation improvement projects. A vital step in the development of this priority array analysis is the identification and evaluation of the various factors which are considered in making highway project priority decisions. We are interested in your judgement of the relative importance of the factors in evaluating the different types of highway improvements, and this is the purpose of this questionnaire.

We have identified 26 factors, which are grouped under 8 broad classes: need, deficiency, continuity, highway-user related, human, economic, social, and environmental. These factors are commonly used in evaluating highway improvement projects. The aim of this questionnaire is to discover the relative importance you assign to each of these factors in evaluating the following 9 types of improvements: new highway construction, reconstruction and major highway upgrading, minor highway upgrading, new structures and replacements, safety improvements, traffic engineering improvements, beautification projects, railroad crossing projects, and special studies.

The completion of this questionnaire will take roughly 45 minutes, which is obviously not a trivial amount of your time. However, if successful, this priority array analysis methodology will greatly streamline and quantify the Department's program development procedures. In addition, it could be very useful to city and county governments and their local and regional planning commissions in developing coordinated transportation capital improvement program. Your assistance in completing the questionnaire would certainly be appreciated. Please return the completed form to the Office of Programming not later than June 13, 1973.

All comments and suggestions concerning additions, changes and improvements will be appreciated.

Please contact this office if you have any questions or if you desire or require additional explanation or assistance.

PRIORITY ARRAY ANALYSIS

FACTOR WEIGHTING FORMS

May 24, 1973

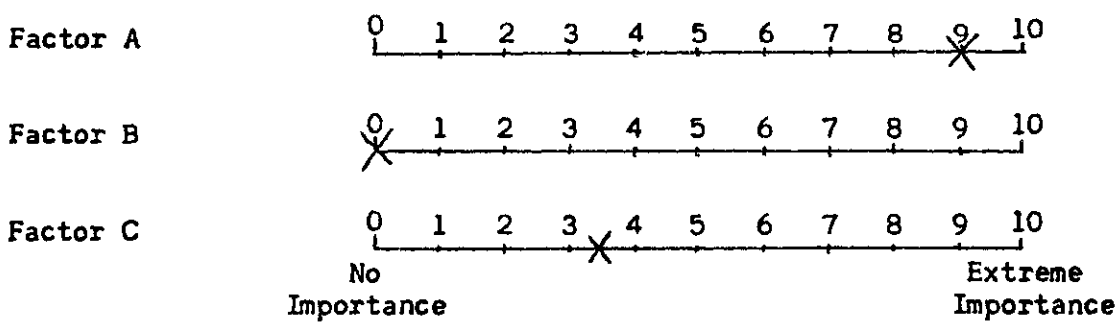
RATING INSTRUCTIONS

On each of the following pages, you are asked to evaluate each of the 26 factors listed in terms of their relative importance for evaluating a type of highway improvement projects (e.g. NEW HIGHWAY CONSTRUCTION on Page 2). Please score each factor on the rating scales provided to the right of the factors.

A rating of zero (0) indicates that the given factor has no importance or is not appropriate for that type of improvement. A rating of ten (10) is the highest that may be assigned to any given factor, indicating extreme importance. Any value on the continuous scale may be assigned to any factor.

Accomplish the desired rating by drawing an (X) on the selected position of the rating scale as shown in the example below.

Example



In the example shown above, the following rates were assigned

Factor A: 9.0

Factor B: 0.0 (Not appropriate for this type of improvement)

Factor C: 3.5

Please score each factor on the rating scales provided (by drawing an (X) on the selected position) in terms of their relative importance for evaluating:

NEW HIGHWAY CONSTRUCTION PROJECTS

(New Highway Construction and Related Engineering Work)

A rating of zero (0) indicates that the given factor has no importance or is not appropriate for this type of improvement. A rating of ten (10) is the highest that may be assigned to any given factor. Any value on the continuous scale may be assigned to any factor.

	FACTOR	IMPORTANCE SCORE (No Importance 0 – 10 Extreme Importance)
NEED FACTORS	Need as identified by state, regional or local transportation plans	0 1 2 3 4 5 6 7 8 9 10
	Need as identified by state, regional or local officials	0 1 2 3 4 5 6 7 8 9 10
	Need as recommended by DOT officials evaluating the project	0 1 2 3 4 5 6 7 8 9 10
DEFICIENCY FACTORS	Existing and projected traffic volume	0 1 2 3 4 5 6 7 8 9 10
	Existing traffic volume/capacity ratio	0 1 2 3 4 5 6 7 8 9 10
	Existing condition of highway facilities	0 1 2 3 4 5 6 7 8 9 10
	Accident experience (including hazard index)	0 1 2 3 4 5 6 7 8 9 10
	Existing deficiencies in roadway geometrics and alignments	0 1 2 3 4 5 6 7 8 9 10
CONTINUITY FACTORS	Continuity with existing facilities	0 1 2 3 4 5 6 7 8 9 10
	Continuity and coordination with other improvements	0 1 2 3 4 5 6 7 8 9 10
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio	0 1 2 3 4 5 6 7 8 9 10
HUMAN FACTOR	Local opinions from publications and hearings as well as requests (or complaints) from local civic groups and individuals	0 1 2 3 4 5 6 7 8 9 10
ECONOMIC FACTORS	Desirability with respect to state, regional and local community goals and long-range, land-use, and economic development plans	0 1 2 3 4 5 6 7 8 9 10
	Consequences on land value and development	0 1 2 3 4 5 6 7 8 9 10
	Consequences on agricultural activities	0 1 2 3 4 5 6 7 8 9 10
	Consequences on commercial and industrial activities	0 1 2 3 4 5 6 7 8 9 10
	Consequences on local construction industry and employment	0 1 2 3 4 5 6 7 8 9 10
	Dislocation and/or relocation of public utilities	0 1 2 3 4 5 6 7 8 9 10
SOCIAL FACTORS	Disruption to community during construction	0 1 2 3 4 5 6 7 8 9 10
	Dislocation and/or relocation of residential and commercial units	0 1 2 3 4 5 6 7 8 9 10
	Consequences on neighborhood life and social patterns	0 1 2 3 4 5 6 7 8 9 10
	Preservation of historical, religious and institutional areas	0 1 2 3 4 5 6 7 8 9 10
ENVIRONMENTAL FACTORS	Aesthetics and visual effects	0 1 2 3 4 5 6 7 8 9 10
	Air pollution, noise pollution and vibration	0 1 2 3 4 5 6 7 8 9 10
	Water pollution and effect on drainage	0 1 2 3 4 5 6 7 8 9 10
	Conservation of Natural resources	0 1 2 3 4 5 6 7 8 9 10

No Importance — Extreme Importance

Please score each factor on the rating scales provided (by drawing an (X) on the selected position) in terms of their relative importance for evaluating:

RECONSTRUCTION AND MAJOR HIGHWAY UPGRADING PROJECTS

(Reconstruction, Relocation, Realignment, Addition of Lane(s), and Widening)

A rating of zero (0) indicates that the given factor has no importance or is not appropriate for this type of improvement. A rating of ten (10) is the highest that may be assigned to any given factor. Any value on the continuous scale may be assigned to any factor.

	FACTOR	IMPORTANCE SCORE (No Importance – Extreme Importance)
NEED FACTORS	Need as identified by state, regional or local transportation plans	0 1 2 3 4 5 6 7 8 9 10
	Need as identified by state, regional or local officials	0 1 2 3 4 5 6 7 8 9 10
	Need as recommended by DOT officials evaluating the project	0 1 2 3 4 5 6 7 8 9 10
DEFICIENCY FACTORS	Existing and projected traffic volume	0 1 2 3 4 5 6 7 8 9 10
	Existing traffic volume/capacity ratio	0 1 2 3 4 5 6 7 8 9 10
	Existing condition of highway facilities	0 1 2 3 4 5 6 7 8 9 10
	Accident experience (including hazard index)	0 1 2 3 4 5 6 7 8 9 10
	Existing deficiencies in roadway geometrics and alignments	0 1 2 3 4 5 6 7 8 9 10
CONTINUITY FACTORS	Continuity with existing facilities	0 1 2 3 4 5 6 7 8 9 10
	Continuity and coordination with other improvements	0 1 2 3 4 5 6 7 8 9 10
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio	0 1 2 3 4 5 6 7 8 9 10
HUMAN FACTOR	Local opinions from publications and hearings as well as requests (or complaints) from local civic groups and individuals	0 1 2 3 4 5 6 7 8 9 10
ECONOMIC FACTORS	Desirability with respect to state, regional and local community goals and long-range, land-use, and economic development plans	0 1 2 3 4 5 6 7 8 9 10
	Consequences on land value and development	0 1 2 3 4 5 6 7 8 9 10
	Consequences on agricultural activities	0 1 2 3 4 5 6 7 8 9 10
	Consequences on commercial and industrial activities	0 1 2 3 4 5 6 7 8 9 10
	Consequences on local construction industry and employment	0 1 2 3 4 5 6 7 8 9 10
	Dislocation and/or relocation of public utilities	0 1 2 3 4 5 6 7 8 9 10
SOCIAL FACTORS	Disruption to community during construction	0 1 2 3 4 5 6 7 8 9 10
	Dislocation and/or relocation of residential and commercial units	0 1 2 3 4 5 6 7 8 9 10
	Consequences on neighborhood life and social patterns	0 1 2 3 4 5 6 7 8 9 10
	Preservation of historial, religious and institutional areas	0 1 2 3 4 5 6 7 8 9 10
ENVIRONMENTAL FACTORS	Aesthetics and visual effects	0 1 2 3 4 5 6 7 8 9 10
	Air pollution, noise pollution and vibration	0 1 2 3 4 5 6 7 8 9 10
	Water pollution and effect on drainage	0 1 2 3 4 5 6 7 8 9 10
	Conservation of Natural resources	0 1 2 3 4 5 6 7 8 9 10

No Importance — Extreme Importance

Please score each factor on the rating scales provided (by drawing an (X) on the selected position) in terms of their relative importance for evaluating:

MINOR HIGHWAY UPGRADING PROJECTS

(Resurfacing, Repaving, Grading, Drainage, Paving Shoulders and Surface Treatment)

A rating of zero (0) indicates that the given factor has no importance or is not appropriate for this type of improvement. A rating of ten (10) is the highest that may be assigned to any given factor. Any value on the continuous scale may be assigned to any factor.

	FACTOR	IMPORTANCE SCORE (No Importance 0 — 10 Extreme Importance)
NEED FACTORS	Need as identified by state, regional or local transportation plans	0 1 2 3 4 5 6 7 8 9 10
	Need as identified by state, regional or local officials	0 1 2 3 4 5 6 7 8 9 10
	Need as recommended by DOT officials evaluating the project	0 1 2 3 4 5 6 7 8 9 10
DEFICIENCY FACTORS	Existing and projected traffic volume	0 1 2 3 4 5 6 7 8 9 10
	Existing traffic volume/capacity ratio	0 1 2 3 4 5 6 7 8 9 10
	Existing condition of highway facilities	0 1 2 3 4 5 6 7 8 9 10
	Accident experience (including hazard index)	0 1 2 3 4 5 6 7 8 9 10
	Existing deficiencies in roadway geometrics and alignments	0 1 2 3 4 5 6 7 8 9 10
CONTINUITY FACTORS	Continuity with existing facilities	0 1 2 3 4 5 6 7 8 9 10
	Continuity and coordination with other improvements	0 1 2 3 4 5 6 7 8 9 10
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio	0 1 2 3 4 5 6 7 8 9 10
HUMAN FACTOR	Local opinions from publications and hearings as well as requests (or compliants) from local civic groups and individuals	0 1 2 3 4 5 6 7 8 9 10
ECONOMIC FACTORS	Desirability with respect to state, regional and local community goals and long-range, land-use, and economic development plans	0 1 2 3 4 5 6 7 8 9 10
	Consequences on land value and development	0 1 2 3 4 5 6 7 8 9 10
	Consequences on agricultural activities	0 1 2 3 4 5 6 7 8 9 10
	Consequences on commercial and industrial activities	0 1 2 3 4 5 6 7 8 9 10
	Consequences on local construction industry and employment	0 1 2 3 4 5 6 7 8 9 10
	Dislocation and/or relocation of public utilities	0 1 2 3 4 5 6 7 8 9 10
SOCIAL FACTORS	Disruption to community during construction	0 1 2 3 4 5 6 7 8 9 10
	Dislocation and/or relocation of residential and commercial units	0 1 2 3 4 5 6 7 8 9 10
	Consequences on neighborhood life and social patterns	0 1 2 3 4 5 6 7 8 9 10
	Preservation of historial, religious and institutional areas	0 1 2 3 4 5 6 7 8 9 10
ENVIRONMENTAL FACTORS	Aesthetics and visual effects	0 1 2 3 4 5 6 7 8 9 10
	Air pollution, noise pollution and vibration	0 1 2 3 4 5 6 7 8 9 10
	Water pollution and effect on drainage	0 1 2 3 4 5 6 7 8 9 10
	Conservation of Natural resources	0 1 2 3 4 5 6 7 8 9 10

No Importance — Extreme Importance

Please score each factor on the rating scales provided (by drawing an (X) on the selected position) in terms of their relative importance for evaluating:

STRUCTURES, NEW AND REPLACEMENTS

(Bridge Structure, Culvert, Sign Support Structure, and Special Structure)

A rating of zero (0) indicates that the given factor has no importance or is not appropriate for this type of improvement. A rating of ten (10) is the highest that may be assigned to any given factor. Any value on the continuous scale may be assigned to any factor.

	FACTOR	IMPORTANCE SCORE (No Importance 0 1 2 3 4 5 6 7 8 9 10 Extreme Importance)
NEED FACTORS	Need as identified by state, regional or local transportation plans	0 1 2 3 4 5 6 7 8 9 10
	Need as identified by state, regional or local officials	0 1 2 3 4 5 6 7 8 9 10
	Need as recommended by DOT officials evaluating the project	0 1 2 3 4 5 6 7 8 9 10
DEFICIENCY FACTORS	Existing and projected traffic volume	0 1 2 3 4 5 6 7 8 9 10
	Existing traffic volume/capacity ratio	0 1 2 3 4 5 6 7 8 9 10
	Existing condition of highway facilities	0 1 2 3 4 5 6 7 8 9 10
	Accident experience (including hazard index)	0 1 2 3 4 5 6 7 8 9 10
	Existing deficiencies in roadway geometrics and alignments	0 1 2 3 4 5 6 7 8 9 10
CONTINUITY FACTORS	Continuity with existing facilities	0 1 2 3 4 5 6 7 8 9 10
	Continuity and coordination with other improvements	0 1 2 3 4 5 6 7 8 9 10
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio	0 1 2 3 4 5 6 7 8 9 10
HUMAN FACTOR	Local opinions from publications and hearings as well as requests (or compliants) from local civic groups and individuals	0 1 2 3 4 5 6 7 8 9 10
ECONOMIC FACTORS	Desirability with respect to state, regional and local community goals and long-range, land-use, and economic development plans	0 1 2 3 4 5 6 7 8 9 10
	Consequences on land value and development	0 1 2 3 4 5 6 7 8 9 10
	Consequences on agricultural activities	0 1 2 3 4 5 6 7 8 9 10
	Consequences on commercial and industrial activities	0 1 2 3 4 5 6 7 8 9 10
	Consequences on local construction industry and employment	0 1 2 3 4 5 6 7 8 9 10
	Dislocation and/or relocation of public utilities	0 1 2 3 4 5 6 7 8 9 10
SOCIAL FACTORS	Disruption to community during construction	0 1 2 3 4 5 6 7 8 9 10
	Dislocation and/or relocation of residential and commercial units	0 1 2 3 4 5 6 7 8 9 10
	Consequences on neighborhood life and social patterns	0 1 2 3 4 5 6 7 8 9 10
	Preservation of historial, religious and institutional areas	0 1 2 3 4 5 6 7 8 9 10
ENVIRONMENTAL FACTORS	Aesthetics and visual effects	0 1 2 3 4 5 6 7 8 9 10
	Air pollution, noise pollution and vibration	0 1 2 3 4 5 6 7 8 9 10
	Water pollution and effect on drainage	0 1 2 3 4 5 6 7 8 9 10
	Conservation of Natural resources	0 1 2 3 4 5 6 7 8 9 10

No Importance — Extreme Importance

Please score each factor on the rating scales provided (by drawing an (X) on the selected position) in terms of their relative importance for evaluating:

SAFETY IMPROVEMENT PROJECTS

(Safety Project, Guardrail, Median, Separator, Sidewalk, and Pedestrain Overpass)

A rating of zero (0) indicates that the given factor has no importance or is not appropriate for this type of improvement. A rating of ten (10) is the highest that may be assigned to any given factor. Any value on the continuous scale may be assigned to any factor.

	FACTOR	IMPORTANCE SCORE (No Importance 0 — 10 Extreme Importance)
NEED FACTORS	Need as identified by state, regional or local transportation plans	0 1 2 3 4 5 6 7 8 9 10
	Need as identified by state, regional or local officials	0 1 2 3 4 5 6 7 8 9 10
	Need as recommended by DOT officials evaluating the project	0 1 2 3 4 5 6 7 8 9 10
DEFICIENCY FACTORS	Existing and projected traffic volume	0 1 2 3 4 5 6 7 8 9 10
	Existing traffic volume/capacity ratio	0 1 2 3 4 5 6 7 8 9 10
	Existing condition of highway facilities	0 1 2 3 4 5 6 7 8 9 10
	Accident experience (including hazard index)	0 1 2 3 4 5 6 7 8 9 10
	Existing deficiencies in roadway geometrics and alignments	0 1 2 3 4 5 6 7 8 9 10
CONTINUITY FACTORS	Continuity with existing facilities	0 1 2 3 4 5 6 7 8 9 10
	Continuity and coordination with other improvements	0 1 2 3 4 5 6 7 8 9 10
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio	0 1 2 3 4 5 6 7 8 9 10
HUMAN FACTOR	Local opinions from publications and hearings as well as requests (or compliants) from local civic groups and individuals	0 1 2 3 4 5 6 7 8 9 10
ECONOMIC FACTORS	Desirability with respect to state, regional and local community goals and long-range, land-use, and economic development plans	0 1 2 3 4 5 6 7 8 9 10
	Consequences on land value and development	0 1 2 3 4 5 6 7 8 9 10
	Consequences on agricultural activities	0 1 2 3 4 5 6 7 8 9 10
	Consequences on commercial and industrial activities	0 1 2 3 4 5 6 7 8 9 10
	Consequences on local construction industry and employment	0 1 2 3 4 5 6 7 8 9 10
	Dislocation and/or relocation of public utilities	0 1 2 3 4 5 6 7 8 9 10
SOCIAL FACTORS	Disruption to community during construction	0 1 2 3 4 5 6 7 8 9 10
	Dislocation and/or relocation of residential and commercial units	0 1 2 3 4 5 6 7 8 9 10
	Consequences on neighborhood life and social patterns	0 1 2 3 4 5 6 7 8 9 10
	Preservation of historial, religious and institutional areas	0 1 2 3 4 5 6 7 8 9 10
ENVIRONMENTAL FACTORS	Aesthetics and visual effects	0 1 2 3 4 5 6 7 8 9 10
	Air pollution, noise pollution and vibration	0 1 2 3 4 5 6 7 8 9 10
	Water pollution and effect on drainage	0 1 2 3 4 5 6 7 8 9 10
	Conservation of Natural resources	0 1 2 3 4 5 6 7 8 9 10

No Importance — Extreme Importance

Please score each factor on the rating scales provided (by drawing an (X) on the selected position) in terms of their relative importance for evaluating:

TRAFFIC ENGINEERING IMPROVEMENT PROJECTS

(TOPICS, Intersection Improvement, Traffic Signal, Flash andOverhead Signing, and Street Lighting)

A rating of zero (0) indicates that the given factor has no importance or is not appropriate for this type of improvement. A rating of ten (10) is the highest that may be assigned to any given factor. Any value on the continuous scale may be assigned to any factor.

	FACTOR	IMPORTANCE SCORE (0 = No Importance, 10 = Extreme Importance)
NEED FACTORS	Need as identified by state, regional or local transportation plans . . .	0 1 2 3 4 5 6 7 8 9 10
	Need as identified by state, regional or local officials	0 1 2 3 4 5 6 7 8 9 10
	Need as recommended by DOT officials evaluating the project	0 1 2 3 4 5 6 7 8 9 10
DEFICIENCY FACTORS	Existing and projected traffic volume	0 1 2 3 4 5 6 7 8 9 10
	Existing traffic volume/capacity ratio	0 1 2 3 4 5 6 7 8 9 10
	Existing condition of highway facilities	0 1 2 3 4 5 6 7 8 9 10
	Accident experience (including hazard index)	0 1 2 3 4 5 6 7 8 9 10
	Existing deficiencies in roadway geometrics and alignments	0 1 2 3 4 5 6 7 8 9 10
CONTINUITY FACTORS	Continuity with existing facilities	0 1 2 3 4 5 6 7 8 9 10
	Continuity and coordination with other improvements	0 1 2 3 4 5 6 7 8 9 10
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio	0 1 2 3 4 5 6 7 8 9 10
HUMAN FACTOR	Local opinions from publications and hearings as well as requests (or complaints) from local civic groups and individuals	0 1 2 3 4 5 6 7 8 9 10
ECONOMIC FACTORS	Desirability with respect to state, regional and local community goals and long-range, land-use, and economic development plans	0 1 2 3 4 5 6 7 8 9 10
	Consequences on land value and development	0 1 2 3 4 5 6 7 8 9 10
	Consequences on agricultural activities	0 1 2 3 4 5 6 7 8 9 10
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	Dislocation and/or relocation of public utilities	0 1 2 3 4 5 6 7 8 9 10
SOCIAL FACTORS	Disruption to community during construction	0 1 2 3 4 5 6 7 8 9 10
	Dislocation and/or relocation of residential and commercial units . . .	0 1 2 3 4 5 6 7 8 9 10
	Consequences on neighborhood life and social patterns	0 1 2 3 4 5 6 7 8 9 10
	Preservation of historial, religious and institutional areas	0 1 2 3 4 5 6 7 8 9 10
ENVIRONMENTAL FACTORS	Aesthetics and visual effects	0 1 2 3 4 5 6 7 8 9 10
	Air pollution, noise pollution and vibration	0 1 2 3 4 5 6 7 8 9 10
	Water pollution and effect on drainage	0 1 2 3 4 5 6 7 8 9 10
	Conservation of Natural resources	0 1 2 3 4 5 6 7 8 9 10

No Importance — Extreme Importance

Please score each factor on the rating scales provided (by drawing an (X) on the selected position) in terms of their relative importance for evaluating:

BEAUTIFICATION PROJECTS

(Landscaping, Rest Area, Scenic Right-of-way Acquisition)

A rating of zero (0) indicates that the given factor has no importance or is not appropriate for this type of improvement. A rating of ten (10) is the highest that may be assigned to any given factor. Any value on the continuous scale may be assigned to any factor.

	FACTOR	IMPORTANCE SCORE (0 = No Importance … 10 = Extreme Importance)
NEED FACTORS	Need as identified by state, regional or local transportation plans	0 1 2 3 4 5 6 7 8 9 10
	Need as identified by state, regional or local officials	0 1 2 3 4 5 6 7 8 9 10
	Need as recommended by DOT officials evaluating the project	0 1 2 3 4 5 6 7 8 9 10
DEFICIENCY FACTORS	Existing and projected traffic volume	0 1 2 3 4 5 6 7 8 9 10
	Existing traffic volume/capacity ratio	0 1 2 3 4 5 6 7 8 9 10
	Existing condition of highway facilities	0 1 2 3 4 5 6 7 8 9 10
	Accident experience (including hazard index)	0 1 2 3 4 5 6 7 8 9 10
	Existing deficiencies in roadway geometrics and alignments	0 1 2 3 4 5 6 7 8 9 10
CONTINUITY FACTORS	Continuity with existing facilities	0 1 2 3 4 5 6 7 8 9 10
	Continuity and coordination with other improvements	0 1 2 3 4 5 6 7 8 9 10
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio	0 1 2 3 4 5 6 7 8 9 10
HUMAN FACTOR	Local opinions from publications and hearings as well as requests (or complaints) from local civic groups and individuals	0 1 2 3 4 5 6 7 8 9 10
ECONOMIC FACTORS	Desirability with respect to state, regional and local community goals and long-range, land-use, and economic development plans	0 1 2 3 4 5 6 7 8 9 10
	Consequences on land value and development	0 1 2 3 4 5 6 7 8 9 10
	Consequences on agricultural activities	0 1 2 3 4 5 6 7 8 9 10
	Consequences on commercial and industrial activities	0 1 2 3 4 5 6 7 8 9 10
	Consequences on local construction industry and employment	0 1 2 3 4 5 6 7 8 9 10
	Dislocation and/or relocation of public utilities	0 1 2 3 4 5 6 7 8 9 10
SOCIAL FACTORS	Disruption to community during construction	0 1 2 3 4 5 6 7 8 9 10
	Dislocation and/or relocation of residential and commercial units	0 1 2 3 4 5 6 7 8 9 10
	Consequences on neighborhood life and social patterns	0 1 2 3 4 5 6 7 8 9 10
	Preservation of historical, religious and institutional areas	0 1 2 3 4 5 6 7 8 9 10
ENVIRONMENTAL FACTORS	Aesthetics and visual effects	0 1 2 3 4 5 6 7 8 9 10
	Air pollution, noise pollution and vibration	0 1 2 3 4 5 6 7 8 9 10
	Water pollution and effect on drainage	0 1 2 3 4 5 6 7 8 9 10
	Conservation of Natural resources	0 1 2 3 4 5 6 7 8 9 10

No Importance … Extreme Importance

Please score each factor on the rating scales provided (by drawing an (X) on the selected position) in terms of their relative importance for evaluating:

RAILROAD CROSSING PROJECTS

(Railroad Overpass, Signal, and Crossing Markings)

A rating of zero (0) indicates that the given factor has no importance or is not appropriate for this type of improvement. A rating of ten (10) is the highest that may be assigned to any given factor. Any value on the continuous scale may be assigned to any factor.

	FACTOR	IMPORTANCE SCORE (No Importance 0 – 10 Extreme Importance)
NEED FACTORS	Need as identified by state, regional or local transportation plans	0 1 2 3 4 5 6 7 8 9 10
	Need as identified by state, regional or local officials	0 1 2 3 4 5 6 7 8 9 10
	Need as recommended by DOT officials evaluating the project	0 1 2 3 4 5 6 7 8 9 10
DEFICIENCY FACTORS	Existing and projected traffic volume	0 1 2 3 4 5 6 7 8 9 10
	Existing traffic volume/capacity ratio	0 1 2 3 4 5 6 7 8 9 10
	Existing condition of highway facilities	0 1 2 3 4 5 6 7 8 9 10
	Accident experience (including hazard index)	0 1 2 3 4 5 6 7 8 9 10
	Existing deficiencies in roadway geometrics and alignments	0 1 2 3 4 5 6 7 8 9 10
CONTINUITY FACTORS	Continuity with existing facilities	0 1 2 3 4 5 6 7 8 9 10
	Continuity and coordination with other improvements	0 1 2 3 4 5 6 7 8 9 10
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio	0 1 2 3 4 5 6 7 8 9 10
HUMAN FACTOR	Local opinions from publications and hearings as well as requests (or complaints) from local civic groups and individuals	0 1 2 3 4 5 6 7 8 9 10
ECONOMIC FACTORS	Desirability with respect to state, regional and local community goals and long-range, land-use, and economic development plans	0 1 2 3 4 5 6 7 8 9 10
	Consequences on land value and development	0 1 2 3 4 5 6 7 8 9 10
	Consequences on agricultural activities	0 1 2 3 4 5 6 7 8 9 10
	Consequences on commercial and industrial activities	0 1 2 3 4 5 6 7 8 9 10
	Consequences on local construction industry and employment	0 1 2 3 4 5 6 7 8 9 10
	Dislocation and/or relocation of public utilities	0 1 2 3 4 5 6 7 8 9 10
SOCIAL FACTORS	Disruption to community during construction	0 1 2 3 4 5 6 7 8 9 10
	Dislocation and/or relocation of residential and commercial units	0 1 2 3 4 5 6 7 8 9 10
	Consequences on neighborhood life and social patterns	0 1 2 3 4 5 6 7 8 9 10
	Preservation of historial, religious and institutional areas	0 1 2 3 4 5 6 7 8 9 10
ENVIRONMENTAL FACTORS	Aesthetics and visual effects	0 1 2 3 4 5 6 7 8 9 10
	Air pollution, noise pollution and vibration	0 1 2 3 4 5 6 7 8 9 10
	Water pollution and effect on drainage	0 1 2 3 4 5 6 7 8 9 10
	Conservation of Natural resources	0 1 2 3 4 5 6 7 8 9 10

No Importance — Extreme Importance

Please score each factor on the rating scales provided (by drawing an (X) on the selected position) in terms of their relative importance for evaluating:

SPECIAL STUDY PROJECTS

(Preliminary Engineering, Survey, Planning, and Research)

A rating of zero (0) indicates that the given factor has no importance or is not appropriate for this type of improvement. A rating of ten (10) is the highest that may be assigned to any given factor. Any value on the continuous scale may be assigned to any factor.

	FACTOR	IMPORTANCE SCORE (0 = No Importance … 10 = Extreme Importance)
NEED FACTORS	Need as identified by state, regional or local transportation plans	0 1 2 3 4 5 6 7 8 9 10
	Need as identified by state, regional or local officials	0 1 2 3 4 5 6 7 8 9 10
	Need as recommended by DOT officials evaluating the project	0 1 2 3 4 5 6 7 8 9 10
DEFICIENCY FACTORS	Existing and projected traffic volume	0 1 2 3 4 5 6 7 8 9 10
	Existing traffic volume/capacity ratio	0 1 2 3 4 5 6 7 8 9 10
	Existing condition of highway facilities	0 1 2 3 4 5 6 7 8 9 10
	Accident experience (including hazard index)	0 1 2 3 4 5 6 7 8 9 10
	Existing deficiencies in roadway geometrics and alignments	0 1 2 3 4 5 6 7 8 9 10
CONTINUITY FACTORS	Continuity with existing facilities	0 1 2 3 4 5 6 7 8 9 10
	Continuity and coordination with other improvements	0 1 2 3 4 5 6 7 8 9 10
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio	0 1 2 3 4 5 6 7 8 9 10
HUMAN FACTOR	Local opinions from publications and hearings as well as requests (or compliants) from local civic groups and individuals	0 1 2 3 4 5 6 7 8 9 10
ECONOMIC FACTORS	Desirability with respect to state, regional and local community goals and long-range, land-use, and economic development plans	0 1 2 3 4 5 6 7 8 9 10
	Consequences on land value and development	0 1 2 3 4 5 6 7 8 9 10
	Consequences on agricultural activities	0 1 2 3 4 5 6 7 8 9 10
	Consequences on commercial and industrial activities	0 1 2 3 4 5 6 7 8 9 10
	Consequences on local construction industry and employment	0 1 2 3 4 5 6 7 8 9 10
	Dislocation and/or relocation of public utilities	0 1 2 3 4 5 6 7 8 9 10
SOCIAL FACTORS	Disruption to community during construction	0 1 2 3 4 5 6 7 8 9 10
	Dislocation and/or relocation of residential and commercial units	0 1 2 3 4 5 6 7 8 9 10
	Consequences on neighborhood life and social patterns	0 1 2 3 4 5 6 7 8 9 10
	Preservation of historial, religious and institutional areas	0 1 2 3 4 5 6 7 8 9 10
ENVIRONMENTAL FACTORS	Aesthetics and visual effects	0 1 2 3 4 5 6 7 8 9 10
	Air pollution, noise pollution and vibration	0 1 2 3 4 5 6 7 8 9 10
	Water pollution and effect on drainage	0 1 2 3 4 5 6 7 8 9 10
	Conservation of Natural resources	0 1 2 3 4 5 6 7 8 9 10

APPENDIX B

GEORGIA STATE TRANSPORTATION BOARD MEMBERS

Appendix B. Georgia State Transportation Board Members

Congressional District	Member
1	Mr. J. O. Bacon
2	Mr. Hugh D. Broome
3	Mr. Frank Morast, Jr.
4	Mr. Jack Embry
5	Mr. Alex W. Smith
6	Mr. Lamar R. Plunkett
7	Mr. Tom Mitchell
8	Mr. W. S. Stuckey, Sr.
9	Mr. Troy Simpson
10	Mr. Douglas D. Barnard, Jr.

APPENDIX C

DEPARTMENT OF TRANSPORTATION RESPONDENTS

Appendix C. Department of Transportation Respondents

1. Mr. Downing Musgrove
   Commissioner

2. Mr. Emory C. Parrish
   Deputy Commissioner

3. Mr. T. D. Moreland
   State Highway Engineer

4. Mr. Florence L. Breen
   Director, Division of Planning and Programming

5. Mr. Jose M. Nieves
   Systems Development Administrator

6. Mr. Hal Rives
   Assistant State Highway Engineer, Pre-Construction

7. Mr. A. S. Mosely
   Assistant State Highway Engineer, Construction

8. Mr. J. D. McGee
   Assistant State Highway Engineer, Operations

9. Mr. J. M. Wilkerson, Jr.
   Assistant State Highway Engineer, Federal-Liaison

10. Mr. J. T. Kratzer
    State Highway Road Design Engineer

11. Mr. L. E. Parker
    State Highway Urban Engineer

12. Mr. R. L. Chapman
    State Highway Bridge Engineer

13. Mr. R. L. Alston
    State Highway Location Engineer

14. Mr. J. E. Brown
    State Highway Right-of-way Engineer

15. Mr. C. H. Breedlove
    State Highway Construction Engineer

16. Mr. W. T. Stapler
    State Highway Materials & Test Engineer

Appendix C. Department of Transportation Respondents (continued)

17. Mr. E. L. Tyre
State Highway Maintenance Engineer

18. Mr. R. C. Tate
State Highway Utilities Engineer

19. Mr. A. C. Burnham
State Highway Traffic & Safety Engineer

20. Mr. Robert C. Kirk
State Transportation Planning Engineer

21. Mr. Jerre Burress
Chief, Plan Development Bureau

22. Mr. Darrell Elwell
Chief, Statewide Planning Branch

23. Mr. N. Mosgovoy
Chief, Urban Planning Branch

24. Mr. Hugh Tyner
Chief, Research & Development Bureau

25. Mr. Drew A. Brown
State Transportation Program Engineer

26. Mr. Emery S. Horvath
Chief, Bureau of Program Development

27. Mr. Randy Elwell
Chief, Bureau of Project Scheduling

28. Mr. F. L. Canup
District Engineer - Gainesville

29. Mr. G. J. Lyons
District Engineer - Tennille

30. Mr. R. E. Brogdon
District Engineer - Thomaston

31. Mr. Earl Olson
District Engineer - Tifton

32. Mr. T. S. McKenzie
District Engineer - Jesup

Appendix C. Department of Transportation Respondents (concluded)

33. Mr. J. W. Wade, Jr.
    District Engineer - Cartersville

34. Mr. Alton L. Dowd, Jr.
    District Engineer - Atlanta

35. Federal Highway Administrator Official.

APPENDIX D

AREA PLANNING AND DEVELOPMENT COMMISSIONS AND URBAN AREA PLANNING COMMISSIONS RESPONDENTS

Appendix D-1. Area Planning and Development Commission Respondents

1. Mr. Jerry O. Bange
   Altamaha Georgia Southern APDC

2. Mr. Tim F. Maund
   Central Savannah River APDC

3. Mr. Wandell E. Brannan
   Chattahoochee-Flint APDC

4. Mr. Vernon D. Martin
   Coastal APDC

5. Mr. Hal A. Davis
   Coastal Plain APDC

6. Mr. Doug R. Hudson
   Coosa Valley APDC

7. Mr. Sam F. Dayton
   Georgia Mountains APDC

8. Mr. Carson O. Porter
   Heart of Georgia APDC

9. Mr. Richard K. Allen
   Lower Chattahoochee Valley APDC

10. Mr. Wade E. Pierce
    McIntosh Trail APDC

11. Mr. Bobby L. Lowe
    Middle Flint APDC

12. Mr. Charles H. Howell
    Middle Georgia APDC

13. Mr. George W. Sutherland
    North Georgia APDC

14. Mr. Clinton R. Lane
    Northeast Georgia APDC

15. Mr. Eugene P. Nuss
    Oconee APDC

16. Mr. Max W. Harral
    Slash Pine APDC

17. Mr. Carroll C. Underwood
    Southwest Georgia APDC

Appendix D-2. Urban Area Planning Commission Respondents

1. Mr. Harry West
   Atlanta Regional Commission

2. Mr. Samuel J. Meltz
   Albany-Dougherty County Planning Commission

3. Mr. Ronald Neisler
   Athens-Clarke County Planning Commission

4. Mr. Dayton L. Sherrouse
   Augusta-Richmond County Planning Commission

5. Mr. Robert E. Gerber
   Columbus Department of Community Development

6. Mr. Ed King
   Dalton-Whitfield County Planning Commission

7. Mr. Edward W. Pollard
   Gainesville-Hall County Planning Commission

8. Mr. John J. Holley
   Macon-Bibb County Planning and Zoning Commission

9. Mr. William H. Dupre, Jr.
   Rome-Floyd County Planning Commission

10. Mr. Howard J. Bellinger
    Chatham County-Savannah Metropolitan Planning Commission

APPENDIX E

SAMPLE COMPUTER PRINTOUTS FROM

'NEW HIGHWAY CONSTRUCTION' TYPE IMPROVEMENT

Appendix E-1. Sample Computer Printout on Factor - Need as Identified by State, Regional and Local Transportation Plans

VARIABLE 1 (NEED1) (PRINTED INTERVAL DESIGNATIONS ARE LOWER LIMITS OF CLASS INTERVALS

TABULATIONS AND COMPUTATIONS WHICH FOLLOW EXCLUDE SPECIAL VALUES

INTERVAL	GROUP 1	GROUP 2	GROUP 3
10.000)	**	**********	*********16
9.500)			
9.000)	***	*******	**
8.500)			
8.000)	*	**	**
7.500)			
7.000)		*****	*
6.500)			
6.000)		*	
5.500)			
5.000)	*	**	**

	GROUP 1	GROUP 2	GROUP 3
MEAN	8.571	8.519	9.174
S DEV	1.718	1.602	1.557
N	7.	27.	23.

ALL GROUPS COMBINED (SPECIAL VALUES EXCLUDED)

MEAN	8.7895
S DEV	1.6006
MAXIMUM	10.0000
MINIMUM	5.0000

	SUM OF SQUARES	DF	MEAN SQUARE	F RATIO
BETWEEN	5.7143	2	2.8572	1.1200
WITHIN	137.7594	54	2.5511	
TOTAL	143.4737	56		

Appendix E-2. Sample Computer Printout on Factor - Existing and Projected Traffic Volume

```
                    VARIABLE   4  ( DEFIC1 )        (PRINTED INTERVAL DESIGNATIONS ARE
                                                     LOWER LIMITS OF CLASS INTERVALS

        GROUP  1   GROUP  2   GROUP  3
        ..........+..........+..........+

        TABULATIONS AND COMPUTATIONS WHICH FOLLOW EXCLUDE SPECIAL VALUES
 INTERVAL

 10.000 )**        ********   ********
  9.000 )**        ****       ***
  8.000 )*         *****      ******
  7.000 )*         ****       *
  6.000 )*         **         *
  5.000 )          **         ***
  4.000 )
  3.000 )          *          *
  2.000 )
  1.000 )
   .000 )          *

 MEAN       8.429     7.741     8.087
 S DEV      1.512     2.427     2.043
 N          7.        27.       23.

ALL GROUPS COMBINED (SPECIAL VALUES EXCLUDED)        SUM OF SQUARES   DF   MEAN SQUARE   F RATIO

        MEAN      7.9649            BETWEEN       3.2042        2      1.6021        .3344
        S DEV     2.1627            WITHIN      258.7255       54      4.7912
        MAXIMUM  10.0000            TOTAL       261.9296       56
        MINIMUM    .0000
```

Appendix E-3. Sample Computer Printout on Factor - Desirability with respect to State. Regional and Local Community Goals and Land-Use and Economic Development Plans.

```
                                   VARIABLE  13  (  ECON1 )          (PRINTED INTERVAL DESIGNATIONS ARE
                                                                      LOWER LIMITS OF CLASS INTERVALS

                GROUP  1   GROUP  2   GROUP  3
                ..........+..........+..........+

               TABULATIONS AND COMPUTATIONS WHICH FOLLOW EXCLUDE SPECIAL VALUES
  INTERVAL

    11.000 )
    10.000 )*        ********  *********16
     9.000 )*****    *********  *
     8.000 )         *******    ****
     7.000 )                    *
     6.000 )*        **         *
     5.000 )
     4.000 )
     3.000 )
     2.000 )         *
     1.000 )

  MEAN          8.714      8.556     9.304
  S DEV         1.254      1.717     1.185
   N            7.         27.       23.
ALL GROUPS COMBINED (SPECIAL VALUES EXCLUDED)              SUM OF SQUARES   DF   MEAN SQUARE   F RATIO

               MEAN       8.8772              BETWEEN      7.1756     2     3.5878      1.6564
               S DEV      1.4889              WITHIN     116.9648    54     2.1660
               MAXIMUM   10.0000              TOTAL      124.1403    56
               MINIMUM    2.0000
```

APPENDIX F

SUMMARY OF RESPONSES FOR THE QUESTIONNAIRE

APPENDIX F

NOMENCLATURE

Level of Dispersion

H - High dispersion, if the standard deviation > 2.98;

M - Medium dispersion, if the standard deviation < 2.98, but > 2.46;

L - Low dispersion, if the standard deviation < 2.46.

Level of Disagreement

H - High disagreement, if the F ratio > 3.17;

M - Medium disagreement, if the F ratio < 3.17, but > 2.41.

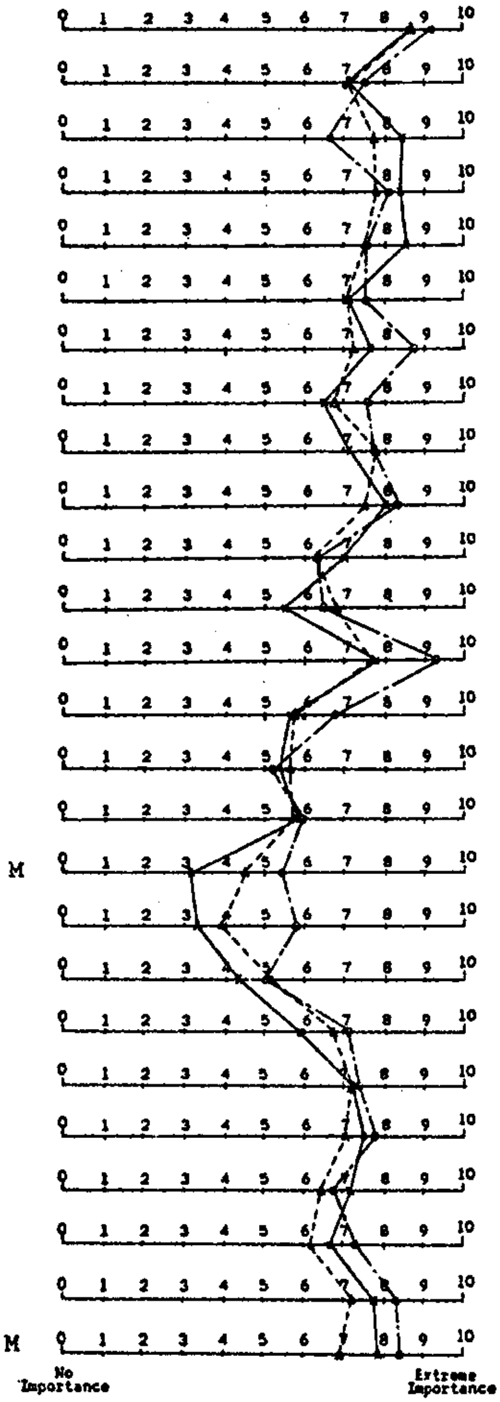
Mean Importance Rating

Group I	State Transportation Board members;
Group II	Department of Transportation officials; and
Group III	Regional and local planners.

Appendix F-1. New Highway Constructions

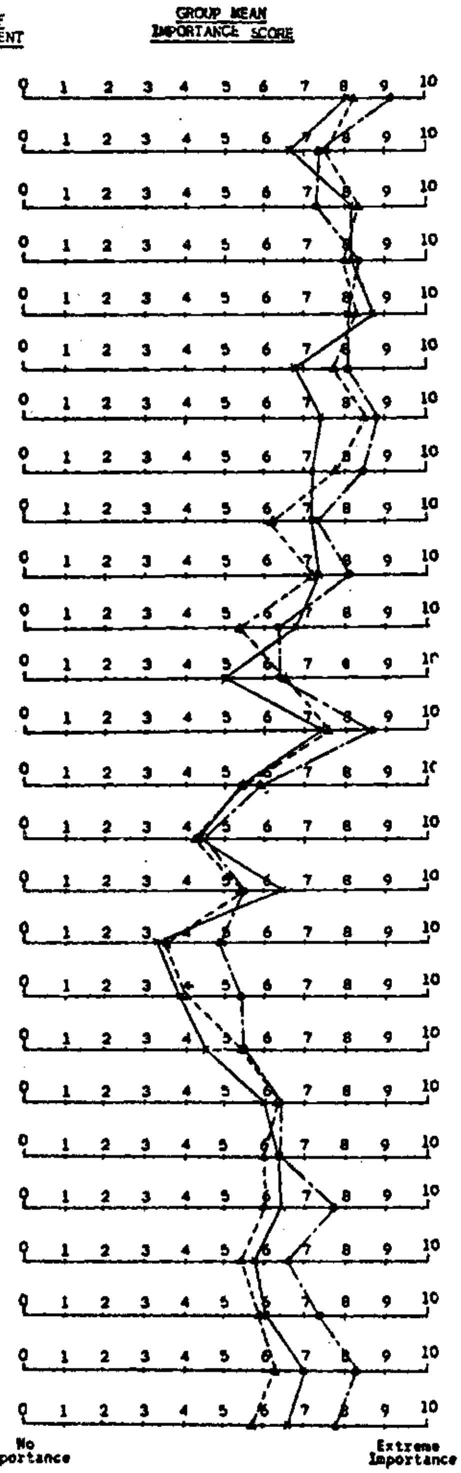
	FACTOR	LEVEL OF DISPERSION	LEVEL OF DISAGREEMENT
NEED FACTORS	Need as identified by state, regional or local transportation plans	L	
	Need as identified by state, regional or local officials	L	
	Need as recommended by DOT officials	L	
DEFICIENCY FACTORS	Existing and projected traffic volume	L	
	Existing traffic volume/capacity ratio	L	H
	Existing condition of highway facilities	L	
	Accident experience	L	
	Existing deficiencies in roadway geometrics and alignments	L	
CONTINUITY FACTORS	Continuity with existing facilities	L	
	Continuity and coordination with other improvements	L	
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio	L	
HUMAN FACTOR	Local opinions	L	
ECONOMIC FACTORS	Desirability with respect to state, regional or local community goals and land-use, and economic development plans	L	
	Consequences on land value and development	M	
	Consequences on agricultural activities	M	
	Consequences on commercial and industrial activities	L	
	Consequences on local construction industry and employment	M	M
	Dislocation and/or relocation of public utilities	M	H
SOCIAL FACTORS	Disruption to community during construction	M	
	Dislocation and/or relocation of residential and commercial units	L	
	Consequences on neighborhood life and social patterns	L	
	Preservation of historical, religious and institutional areas	L	
ENVIRONMENTAL FACTORS	Aesthetics and visual effects	L	
	Air pollution, noise pollution and vibration	M	
	Water pollution and effect on drainage	L	
	Conservation of Natural resources	L	M

GROUP MEAN IMPORTANCE SCORE



Appendix F-2. Reconstruction and Major Highway Upgrading

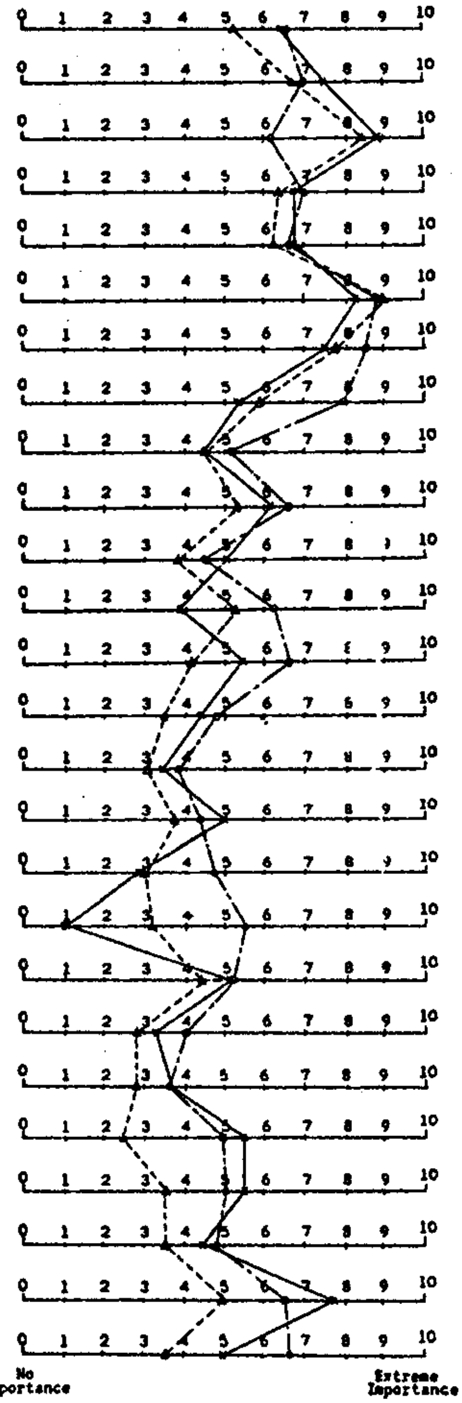
	FACTOR	LEVEL OF DISPERSION	LEVEL OF DISAGREEMENT
NEED FACTORS	Need as identified by state, regional or local transportation plans	L	M
	Need as identified by state, regional or local officials	L	
	Need as recommended by DOT officials	L	
DEFICIENCY FACTORS	Existing and projected traffic volume	L	
	Existing traffic volume/capacity ratio	L	
	Existing condition of highway facilities	L	
	Accident experience	L	M
	Existing deficiencies in roadway geometrics and alignments	L	
CONTINUITY FACTORS	Continuity with existing facilities	M	
	Continuity and coordination with other improvements	L	
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio	M	
HUMAN FACTOR	Local opinions	L	
ECONOMIC FACTORS	Desirability with respect to state, regional or local community goals and land-use, and economic development plans	L	H
	Consequences on land value and development	L	
	Consequences on agricultural activities	L	
	Consequences on commercial and industrial activities	L	
	Consequences on local construction industry and employment	M	M
	Dislocation and/or relocation of public utilities	M	
SOCIAL FACTORS	Disruption to community during construction	M	
	Dislocation and/or relocation of residential and commercial units	L	
	Consequences on neighborhood life and social patterns	M	M
	Preservation of historial, religious and institutional areas	M	
ENVIRONMENTAL FACTORS	Aesthetics and visual effects	M	
	Air pollution, noise pollution and vibration	M	
	Water pollution and effect on drainage	M	H
	Conservation of Natural resources	M	H



Appendix F-3. Minor Highway Upgrading

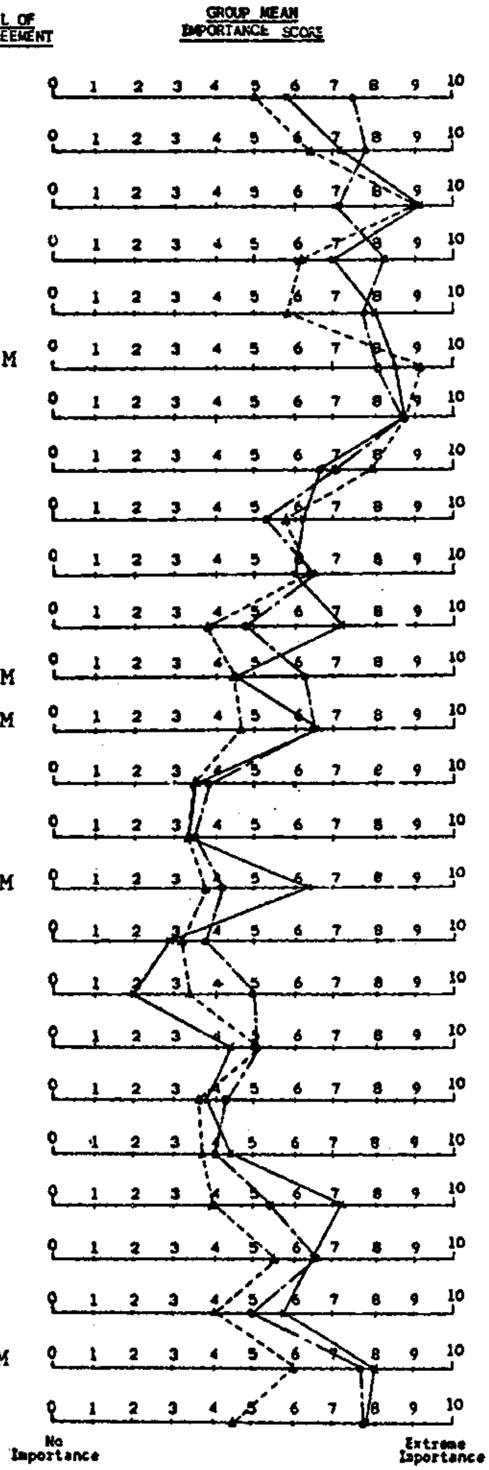
	FACTOR	LEVEL OF DISPERSION	LEVEL OF DISAGREEMENT
NEED FACTORS	Need as identified by state, regional or local transportation plans	H	
	Need as identified by state, regional or local officials	M	
	Need as recommended by DOT officials	L	H
DEFICIENCY FACTORS	Existing and projected traffic volume	L	
	Existing traffic volume/capacity ratio	M	
	Existing condition of highway facilities	L	
	Accident experience	L	
	Existing deficiencies in roadway geometrics and alignments	H	H
CONTINUITY FACTORS	Continuity with existing facilities	H	
	Continuity and coordination with other improvements	M	
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio	H	
HUMAN FACTOR	Local opinions	M	
ECONOMIC FACTORS	Desirability with respect to state, regional or local community goals and land-use, and economic development plans	H	H
	Consequences on land value and development	M	
	Consequences on agricultural activities	M	
	Consequences on commercial and industrial activities	M	
	Consequences on local construction industry and employment	M	H
	Dislocation and/or relocation of public utilities	H	H
SOCIAL FACTORS	Disruption to community during construction	H	
	Dislocation and/or relocation of residential and commercial units	H	
	Consequences on neighborhood life and social patterns	H	
	Preservation of historial, religious and institutional areas	H	H
ENVIRONMENTAL FACTORS	Aesthetics and visual effects	M	M
	Air pollution, noise pollution and vibration	H	
	Water pollution and effect on drainage	H	M
	Conservation of Natural resources	H	H

GROUP MEAN IMPORTANCE SCORE



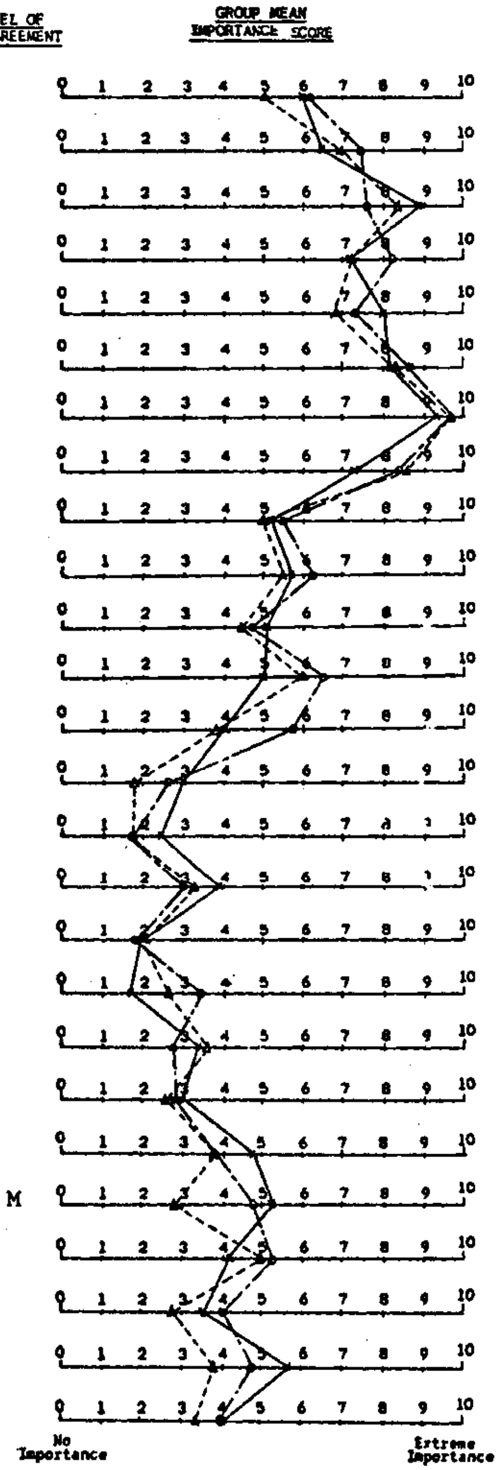
Appendix F-4. Structures, New and Replacements

	FACTOR	LEVEL OF DISPERSION	LEVEL OF DISAGREEMENT
NEED FACTORS	Need as identified by state, regional or local transportation plans	H	H
	Need as identified by state, regional or local officials	M	
	Need as recommended by DOT officials	L	H
DEFICIENCY FACTORS	Existing and projected traffic volume	M	H
	Existing traffic volume/capacity ratio	H	H
	Existing condition of highway facilities	L	M
	Accident experience	L	
	Existing deficiencies in roadway geometrics and alignments	M	
CONTINUITY FACTORS	Continuity with existing facilities	M	
	Continuity and coordination with other improvements	M	
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio	H	H
HUMAN FACTOR	Local opinions	M	M
ECONOMIC FACTORS	Desirability with respect to state, regional or local community goals and land-use, and economic development plans	H	M
	Consequences on land value and development	M	
	Consequences on agricultural activities	M	
	Consequences on commercial and industrial activities	M	M
	Consequences on local construction industry and employment	M	
	Dislocation and/or relocation of public utilities	M	H
SOCIAL FACTORS	Disruption to community during construction	M	
	Dislocation and/or relocation of residential and commercial units	H	
	Consequences on neighborhood life and social patterns	H	
	Preservation of historial, religious and institutional areas	H	H
ENVIRONMENTAL FACTORS	Aesthetics and visual effects	M	
	Air pollution, noise pollution and vibration	H	
	Water pollution and effect on drainage	M	M
	Conservation of Natural resources	H	H



Appendix F-5. Safety Improvements

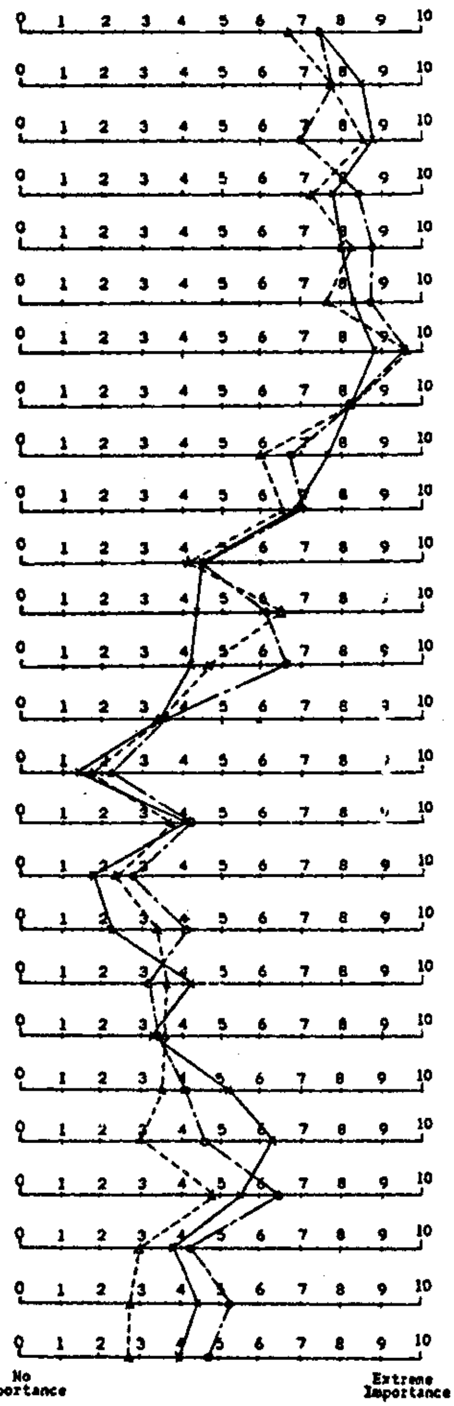
	FACTOR	LEVEL OF DISPERSION	LEVEL OF DISAGREEMENT
NEED FACTORS	Need as identified by state, regional or local transportation plans	H	
	Need as identified by state, regional or local officials	M	
	Need as recommended by DOT officials	L	
DEFICIENCY FACTORS	Existing and projected traffic volume	L	
	Existing traffic volume/capacity ratio	M	
	Existing condition of highway facilities	L	
	Accident experience	L	
	Existing deficiencies in roadway geometrics and alignments	M	
CONTINUITY FACTORS	Continuity with existing facilities	H	
	Continuity and coordination with other improvements	M	
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio	H	
HUMAN FACTOR	Local opinions	M	
ECONOMIC FACTORS	Desirability with respect to state, regional or local community goals and land-use, and economic development plans	H	
	Consequences on land value and development	M	
	Consequences on agricultural activities	L	
	Consequences on commercial and industrial activities	M	
	Consequences on local construction industry and employment	L	
	Dislocation and/or relocation of public utilities	M	
SOCIAL FACTORS	Disruption to community during construction	M	
	Dislocation and/or relocation of residential and commercial units	M	
	Consequences on neighborhood life and social patterns	H	
	Preservation of historial, religious and institutional areas	H	M
ENVIRONMENTAL FACTORS	Aesthetics and visual effects	M	
	Air pollution, noise pollution and vibration	H	
	Water pollution and effect on drainage	H	
	Conservation of Natural resources	H	



Appendix F-6. Traffic Engineering Improvements

	FACTOR	LEVEL OF DISPERSION	LEVEL OF DISAGREEMENT
NEED FACTORS	Need as identified by state, regional or local transportation plans	M	
	Need as identified by state, regional or local officials	L	
	Need as recommended by DOT officials	L	H
DEFICIENCY FACTORS	Existing and projected traffic volume	L	
	Existing traffic volume/capacity ratio	L	
	Existing condition of highway facilities	L	
	Accident experience	L	
	Existing deficiencies in roadway geometrics and alignments	M	
CONTINUITY FACTORS	Continuity with existing facilities	M	
	Continuity and coordination with other improvements	M	
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio	H	
HUMAN FACTOR	Local opinions	M	
ECONOMIC FACTORS	Desirability with respect to state, regional or local community goals and land-use, and economic development plans	H	M
	Consequences on land value and development	M	
	Consequences on agricultural activities	L	
	Consequences on commercial and industrial activities	M	
	Consequences on local construction industry and employment	L	
	Dislocation and/or relocation of public utilities	M	
SOCIAL FACTORS	Disruption to community during construction	M	
	Dislocation and/or relocation of residential and commercial units	H	
	Consequences on neighborhood life and social patterns	H	
	Preservation of historial, religious and institutional areas	H	H
ENVIRONMENTAL FACTORS	Aesthetics and visual effects	H	
	Air pollution, noise pollution and vibration	H	
	Water pollution and effect on drainage	H	M
	Conservation of Natural resources	H	

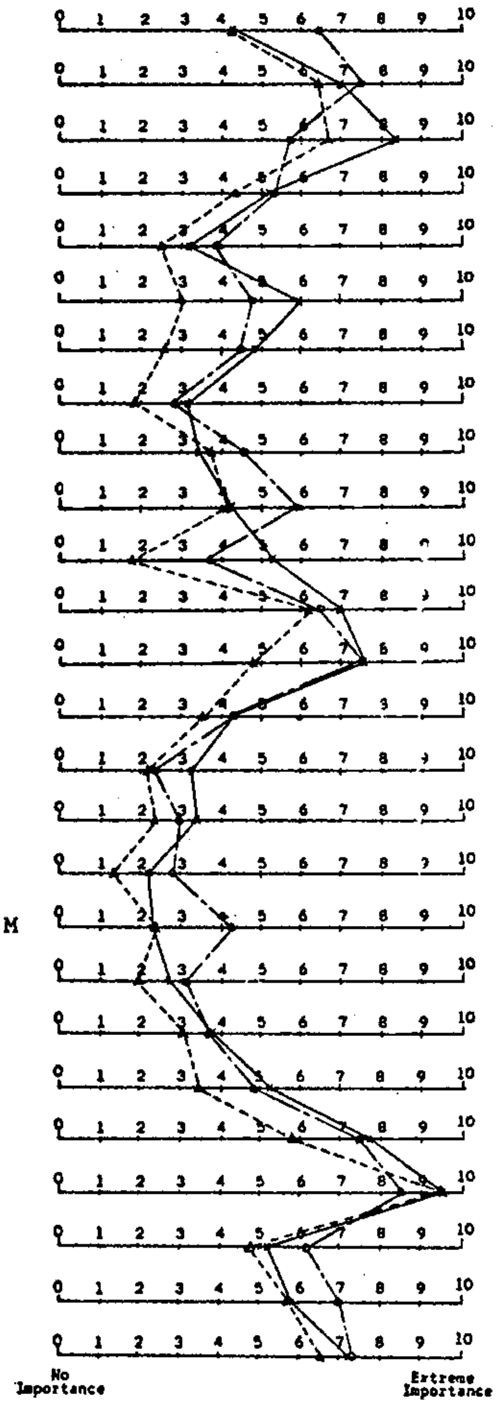
GROUP MEAN IMPORTANCE SCORE



Appendix F-7. Beautification Projects

	FACTOR	LEVEL OF DISPERSION	LEVEL OF DISAGREEMENT
NEED FACTORS	Need as identified by state, regional or local transportation plans	H	
	Need as identified by state, regional or local officials	M	
	Need as recommended by DOT officials	H	
DEFICIENCY FACTORS	Existing and projected traffic volume	H	
	Existing traffic volume/capacity ratio	H	
	Existing condition of highway facilities	H	
	Accident experience	H	
	Existing deficiencies in roadway geometrics and alignments	H	
CONTINUITY FACTORS	Continuity with existing facilities	H	
	Continuity and coordination with other improvements	H	
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio	H	H
HUMAN FACTOR	Local opinions	M	
ECONOMIC FACTORS	Desirability with respect to state, regional or local community goals and land-use, and economic development plans	H	H
	Consequences on land value and development	H	
	Consequences on agricultural activities	M	
	Consequences on commercial and industrial activities	M	
	Consequences on local construction industry and employment	M	
	Dislocation and/or relocation of public utilities	M	M
SOCIAL FACTORS	Disruption to community during construction	M	
	Dislocation and/or relocation of residential and commercial units	H	
	Consequences on neighborhood life and social patterns	H	
	Preservation of historial, religious and institutional areas	H	
ENVIRONMENTAL FACTORS	Aesthetics and visual effects	L	
	Air pollution, noise pollution and vibration	H	
	Water pollution and effect on drainage	H	
	Conservation of Natural resources	H	

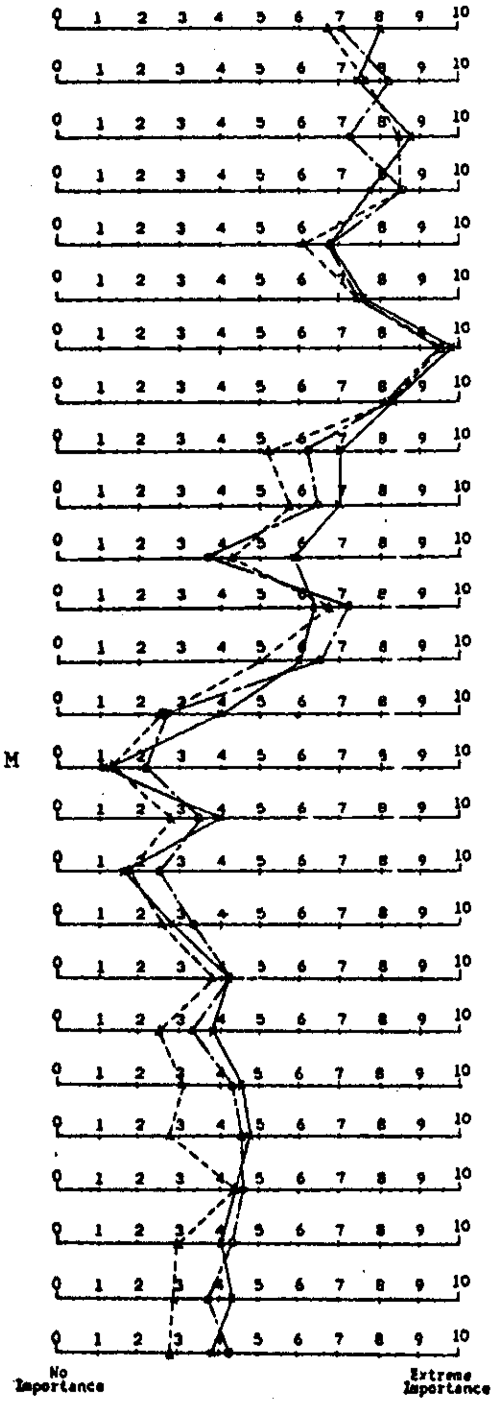
GROUP MEAN IMPORTANCE SCORE



Appendix F-8. Railroad Crossing Projects

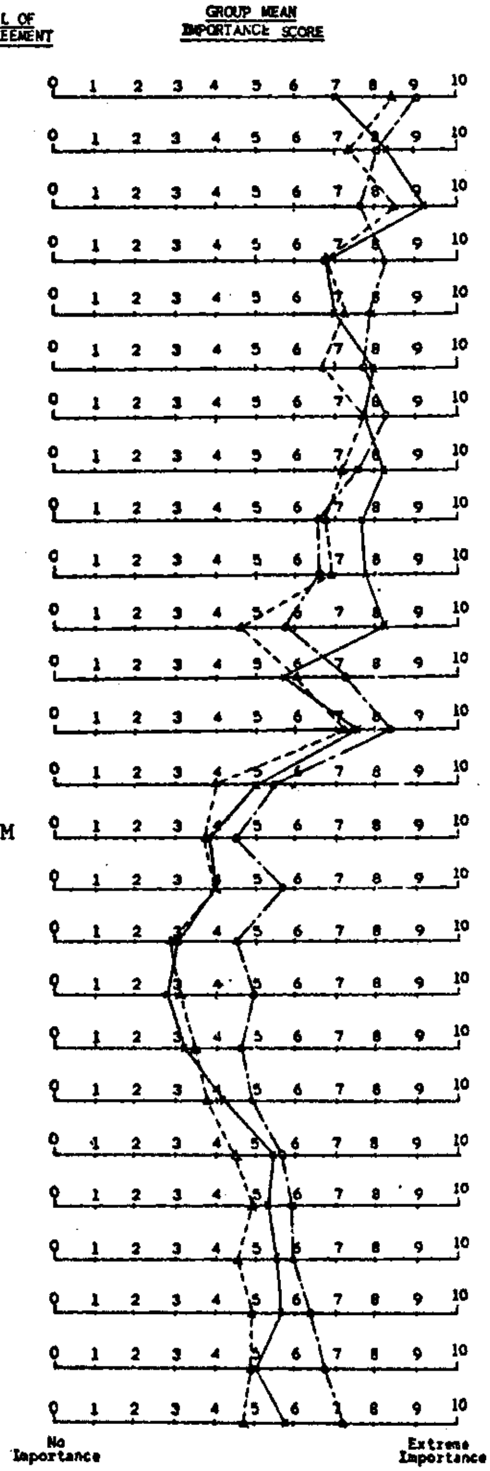
	FACTOR	LEVEL OF DISPERSION	LEVEL OF DISAGREEMENT
NEED FACTORS	Need as identified by state, regional or local transportation plans	H	
	Need as identified by state, regional or local officials	L	
	Need as recommended by DOT officials	L	
DEFICIENCY FACTORS	Existing and projected traffic volume	L	
	Existing traffic volume/capacity ratio	H	
	Existing condition of highway facilities	M	
	Accident experience	L	
	Existing deficiencies in roadway geometrics and alignments	L	
CONTINUITY FACTORS	Continuity with existing facilities	H	
	Continuity and coordination with other improvements	M	
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio	H	
HUMAN FACTOR	Local opinions	L	
ECONOMIC FACTORS	Desirability with respect to state, regional or local community goals and land-use, and economic development plans	H	
	Consequences on land value and development	M	
	Consequences on agricultural activities	L	M
	Consequences on commercial and industrial activities	M	
	Consequences on local construction industry and employment	L	
	Dislocation and/or relocation of public utilities	M	
SOCIAL FACTORS	Disruption to community during construction	H	
	Dislocation and/or relocation of residential and commercial units	M	
	Consequences on neighborhood life and social patterns	H	
	Preservation of historial, religious and institutional areas	H	
ENVIRONMENTAL FACTORS	Aesthetics and visual effects	H	
	Air pollution, noise pollution and vibration	H	
	Water pollution and effect on drainage	H	
	Conservation of Natural resources	H	

GROUP MEAN IMPORTANCE SCORE



Appendix F-9. Special Projects

	FACTOR	LEVEL OF DISPERSION	LEVEL OF DISAGREEMENT
NEED FACTORS	Need as identified by state, regional or local transportation plans	H	
	Need as identified by state, regional or local officials	L	
	Need as recommended by DOT officials	L	
DEFICIENCY FACTORS	Existing and projected traffic volume	L	
	Existing traffic volume/capacity ratio	H	
	Existing condition of highway facilities	M	
	Accident experience	L	
	Existing deficiencies in roadway geometrics and alignments	L	
CONTINUITY FACTORS	Continuity with existing facilities	H	
	Continuity and coordination with other improvements	M	
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio	H	
HUMAN FACTOR	Local opinions	L	
ECONOMIC FACTORS	Desirability with respect to state, regional or local community goals and land-use, and economic development plans	H	
	Consequences on land value and development	M	
	Consequences on agricultural activities	L	M
	Consequences on commercial and industrial activities	M	
	Consequences on local construction industry and employment	L	
	Dislocation and/or relocation of public utilities	M	
SOCIAL FACTORS	Disruption to community during construction	H	
	Dislocation and/or relocation of residential and commercial units	M	
	Consequences on neighborhood life and social patterns	H	
	Preservation of historial, religious and institutional areas	H	
ENVIRONMENTAL FACTORS	Aesthetics and visual effects	H	
	Air pollution, noise pollution and vibration	H	
	Water pollution and effect on drainage	H	
	Conservation of Natural resources	H	



APPENDIX G

COMMON-FACTORS AND FACTOR LOADINGS

Appendix G-1. New Highway Constructions

	FACTOR	Common-Factor 1	2	3	4	5	6	7
NEED FACTORS	Need as identified by state, regional or local transportation plans				0.85			
	Need as identified by state, regional or local officials			0.51				
	Need as recommended by DOT officials						0.72	
DEFICIENCY FACTORS	Existing and projected traffic volume						0.79	
	Existing traffic volume/capacity ratio		0.84					
	Existing condition of highway facilities		0.89					
	Accident experience		0.92					
	Existing deficiencies in roadway geometrics and alignments		0.92					
CONTINUITY FACTORS	Continuity with existing facilities					0.74		
	Continuity and coordination with other improvements							
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio						0.71	
HUMAN FACTOR	Local opinions							0.7(
ECONOMIC FACTORS	Desirability with respect to state, regional or local community goals and land-use, and economic development plans				0.84			
	Consequences on land value and development			0.70				
	Consequences on agricultural activities			0.61				
	Consequences on commercial and industrial activities			0.80				
	Consequences on local construction industry and employment			0.78				
	Dislocation and/or relocation of public utilities			0.67				
SOCIAL FACTORS	Disruption to community during construction					0.74		
	Dislocation and/or relocation of residential and commercial units	0.47						
	Consequences on neighborhood life and social patterns	0.55						
	Preservation of historial, religious and institutional areas	0.71						
ENVIRONMENTAL FACTORS	Aesthetics and visual effects	0.83						
	Air pollution, noise pollution and vibration	0.85						
	Water pollution and effect on drainage	0.91						
	Conservation of Natural resources	0.87						

Appendix G-2. Reconstruction and Major Highway Upgrading

	FACTOR	Common-Factor 1	2	3	4	5	6
NEED FACTORS	Need as identified by state, regional or local transportation plans	0.46					
	Need as identified by state, regional or local officials				0.47		
	Need as recommended by DOT officials			0.80			
DEFICIENCY FACTORS	Existing and projected traffic volume			0.85			
	Existing traffic volume/capacity ratio			0.81			
	Existing condition of highway facilities		0.83				
	Accident experience					0.81	
	Existing deficiencies in roadway geometrics and alignments		0.89				
CONTINUITY FACTORS	Continuity with existing facilities				0.52		
	Continuity and coordination with other improvements				0.57		
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio						
[illegible] FACTOR	Local opinions						0.56
ECONOMIC FACTORS	Desirability with respect to state, regional or local community goals and land-use, and economic development plans	0.49				0.52	
	Consequences on land value and development	0.45			0.51		
	Consequences on agricultural activities						0.79
	Consequences on commercial and industrial activities				0.83		
	Consequences on local construction industry and employment						0.60
	Dislocation and/or relocation of public utilities						0.46
SOCIAL FACTORS	Disruption to community during construction	0.76					
	Dislocation and/or relocation of residential and commercial units	0.79					
	Consequences on neighborhood life and social patterns	0.78					
	Preservation of historial, religious and institutional areas	0.77					
ENVIRONMENTAL FACTORS	Aesthetics and visual effects	0.78					
	Air pollution, noise pollution and vibration	0.82					
	Water pollution and effect on drainage	0.69					
	Conservation of Natural resources	0.70					

Appendix G-3. Minor Highway Upgrading

	FACTOR	Common-Factor 1	2	3	4	5	6	7
NEED FACTORS	Need as identified by state, regional or local transportation plans					0.77		
	Need as identified by state, regional or local officials							0.93
	Need as recommended by DOT officials						-0.89	
DEFICIENCY FACTORS	Existing and projected traffic volume							0.43
	Existing traffic volume/capacity ratio							
	Existing condition of highway facilities		0.85					
	Accident experience							
	Existing deficiencies in roadway geometrics and alignments						0.51	
CONTINUITY FACTORS	Continuity with existing facilities							
	Continuity and coordination with other improvements							
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio					0.59		
HUMAN FACTOR	Local opinions							
ECONOMIC FACTORS	Desirability with respect to state, regional or local community goals and land-use, and economic development plans					0.68		
	Consequences on land value and development			0.79				
	Consequences on agricultural activities			0.79				
	Consequences on commercial and industrial activities			0.81				
	Consequences on local construction industry and employment			0.70				
	Dislocation and/or relocation of public utilities			0.49			0.54	
SOCIAL FACTORS	Disruption to community during construction	0.45		0.46				
	Dislocation and/or relocation of residential and commercial units	0.79						
	Consequences on neighborhood life and social patterns	0.88						
	Preservation of historial, religious and institutional areas	0.72						
ENVIRONMENTAL FACTORS	Aesthetics and visual effects				0.74			
	Air pollution, noise pollution and vibration				0.62			
	Water pollution and effect on drainage				0.74			
	Conservation of Natural resources				0.76			

Appendix G-4. Structures, New and Replacements

	FACTOR	Common-Factor 1	2	3	4	5	6	7
NEED FACTORS	Need as identified by state, regional or local transportation plans				0.48			0.63
	Need as identified by state, regional or local officials				0.49			
	Need as recommended by DOT officials		0.90					
DEFICIENCY FACTORS	Existing and projected traffic volume				0.87			
	Existing traffic volume/capacity ratio				0.91			
	Existing condition of highway facilities		0.86					
	Accident experience					0.67		
	Existing deficiencies in roadway geometrics and alignments					0.83		
CONTINUITY FACTORS	Continuity with existing facilities			0.86				
	Continuity and coordination with other improvements			0.87				
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio							
HUMAN FACTOR	Local opinions							
ECONOMIC FACTORS	Desirability with respect to state, regional or local community goals and land-use, and economic development plans						0.43	
	Consequences on land value and development						0.43	
	Consequences on agricultural activities						0.83	
	Consequences on commercial and industrial activities						0.52	
	Consequences on local construction industry and employment						0.83	
	Dislocation and/or relocation of public utilities						0.77	
SOCIAL FACTORS	Disruption to community during construction	0.61						
	Dislocation and/or relocation of residential and commercial units	0.88						
	Consequences on neighborhood life and social patterns	0.90						
	Preservation of historial, religious and institutional areas	0.59						
ENVIRONMENTAL FACTORS	Aesthetics and visual effects							0.79
	Air pollution, noise pollution and vibration	0.66						
	Water pollution and effect on drainage							0.81
	Conservation of Natural resources	0.56						0.56

Appendix G-5. Safety Improvements

	FACTOR	Common-Factor 1	2	3	4	5	6	7
NEED FACTORS	Need as identified by state, regional or local transportation plans				0.58			
	Need as identified by state, regional or local officials		0.94					
	Need as recommended by DOT officials							0.71
DEFICIENCY FACTORS	Existing and projected traffic volume						0.71	
	Existing traffic volume/capacity ratio							
	Existing condition of highway facilities					0.78		
	Accident experience					0.78		
	Existing deficiencies in roadway geometrics and alignments			0.85				
CONTINUITY FACTORS	Continuity with existing facilities							0.52
	Continuity and coordination with other improvements							0.78
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio							
HUMAN FACTOR	Local opinions							
ECONOMIC FACTORS	Desirability with respect to state, regional or local community goals and land-use, and economic development plans				0.71			
	Consequences on land value and development	0.75						
	Consequences on agricultural activities	0.81						
	Consequences on commercial and industrial activities	0.80						
	Consequences on local construction industry and employment	0.72						
	Dislocation and/or relocation of public utilities						0.65	
SOCIAL FACTORS	Disruption to community during construction							
	Dislocation and/or relocation of residential and commercial units				0.53			
	Consequences on neighborhood life and social patterns				0.50			
	Preservation of historial, religious and institutional areas	0.60			0.52			
ENVIRONMENTAL FACTORS	Aesthetics and visual effects							
	Air pollution, noise pollution and vibration				0.79			
	Water pollution and effect on drainage				0.74			
	Conservation of Natural resources				0.83			

Appendix G-6. Traffic Engineering Improvements

	FACTOR	Common-Factor 1	2	3	4	5	6	7
NEED FACTORS	Need as identified by state, regional or local transportation plans							
	Need as identified by state, regional or local officials			0.83				
	Need as recommended by DOT officials			0.85				
DEFICIENCY FACTORS	Existing and projected traffic volume		0.91					
	Existing traffic volume/capacity ratio		0.63					
	Existing condition of highway facilities							0.84
	Accident experience							0.61
	Existing deficiencies in roadway geometrics and alignments				0.79			
CONTINUITY FACTORS	Continuity with existing facilities				0.80			
	Continuity and coordination with other improvements				0.78			
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio							
HUMAN FACTOR	Local opinions						0.89	
ECONOMIC FACTORS	Desirability with respect to state, regional or local community goals and land-use, and economic development plans	0.54						
	Consequences on land value and development	0.57						
	Consequences on agricultural activities							
	Consequences on commercial and industrial activities					0.86		
	Consequences on local construction industry and employment	0.56						
	Dislocation and/or relocation of public utilities							
SOCIAL FACTORS	Disruption to community during construction	0.78						
	Dislocation and/or relocation of residential and commercial units	0.80						
	Consequences on neighborhood life and social patterns	0.75						
	Preservation of historial, religious and institutional areas	0.72						
ENVIRONMENTAL FACTORS	Aesthetics and visual effects	0.55						
	Air pollution, noise pollution and vibration	0.84						
	Water pollution and effect on drainage	0.77						
	Conservation of Natural resources	0.86						

Appendix G-7. Beautification Projects

	FACTOR	Common-Factor 1	2	3	4	5	6	7
NEED FACTORS	Need as identified by state, regional or local transportation plans							0.57
	Need as identified by state, regional or local officials							0.90
	Need as recommended by DOT officials					0.84		
DEFICIENCY FACTORS	Existing and projected traffic volume		0.89					
	Existing traffic volume/capacity ratio		0.75					
	Existing condition of highway facilities		0.47					
	Accident experience		0.72					
	Existing deficiencies in roadway geometrics and alignments		0.69					
CONTINUITY FACTORS	Continuity with existing facilities							
	Continuity and coordination with other improvements							
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio							
HUMAN FACTOR	Local opinions							
ECONOMIC FACTORS	Desirability with respect to state, regional or local community goals and land-use, and economic development plans			0.71				
	Consequences on land value and development	0.83						
	Consequences on agricultural activities	0.83						
	Consequences on commercial and industrial activities	0.91						
	Consequences on local construction industry and employment	0.67						
	Dislocation and/or relocation of public utilities	0.47			0.46			
SOCIAL FACTORS	Disruption to community during construction				0.83			
	Dislocation and/or relocation of residential and commercial units				0.73			
	Consequences on neighborhood life and social patterns				0.70			
	Preservation of historial, religious and institutional areas			0.81				
ENVIRONMENTAL FACTORS	Aesthetics and visual effects						0.90	
	Air pollution, noise pollution and vibration				0.68			
	Water pollution and effect on drainage			0.48	0.52			
	Conservation of Natural resources			0.68				

Appendix G-8. Railroad Crossing Projects

	FACTOR	Common-Factor 1	2	3	4	5	6
NEED FACTORS	Need as identified by state, regional or local transportation plans		0.52				
	Need as identified by state, regional or local officials		0.62				
	Need as recommended by DOT officials			0.79			
DEFICIENCY FACTORS	Existing and projected traffic volume		0.69				
	Existing traffic volume/capacity ratio		0.71				
	Existing condition of highway facilities		0.50				
	Accident experience			0.88			
	Existing deficiencies in roadway geometrics and alignments			0.74			
CONTINUITY FACTORS	Continuity with existing facilities				0.86		
	Continuity and coordination with other improvements				0.82		
HIGHWAY-USER RELATED FACTOR	Benefit-cost ratio						0.84
HUMAN FACTOR	Local opinions			0.59			
ECONOMIC FACTORS	Desirability with respect to state, regional or local community goals and land-use, and economic development plans .				0.51		
	Consequences on land value and development					0.71	
	Consequences on agricultural activities					0.72	
	Consequences on commercial and industrial activities					0.82	
	Consequences on local construction industry and employment					0.81	
	Dislocation and/or relocation of public utilities					0.61	
SOCIAL FACTORS	Disruption to community during construction . . .	0.72					
	Dislocation and/or relocation of residential and commercial units . . .	0.87					
	Consequences on neighborhood life and social patterns . . .	0.74					
	Preservation of historial, religious and institutional areas	0.87					
ENVIRONMENTAL FACTORS	Aesthetics and visual effects	0.68					
	Air pollution, noise pollution and vibration . . .	0.56					
	Water pollution and effect on drainage	0.69					
	Conservation of Natural resources	0.83					

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